Power basics for IT professionals

technology brief

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Abstract

In the next decade, power, with its attendant heating, cooling, cost, reliability and dependability issues, will be the greatest challenge for the vast majority of data center operations. IT professionals attempting to deal with the power challenge need a working understanding of the power terms, concepts, and facts covered in this paper.

This paper is intended primarily as an aid to IT professionals who are not fully familiar with power and its general concepts. The paper offers basic information about power in data centers and other IT environments. It explains how power is generated, transmitted, and delivered to IT operations, especially the data center. It also explains the importance of anticipating future IT growth and the need to provide adequate power to support that growth. This paper provides definitions and explanations of electric power in its most general and typical usage and implementation. The paper does not cover exhaustive details about exceptions to general practices.

Introduction

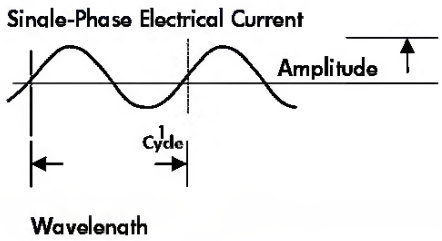
Electric power—its generation, transmission, distribution and ultimate use by HP ProLiant servers—is a complex supply chain. Customers must understand and consider a host of power terms, standards, and technical issues to enable their data centers to function as efficiently and economically as possible, now and in the future. This understanding becomes critical as the density of server configurations increases in the next few years.

This paper provides an explanation of basic power concepts, terms, and introduction to general concepts for power distribution to IT data centers. It includes an extensive glossary for definitions of common terms. Finally, the "For More Information" section identifies additional references to standards and to technology briefs on specific power-related topics.

General terms

Alternating current (AC) is typically expressed in terms of voltage amplitude in volts and current amplitude in amperes. Its waveform is a sine wave with properties of length (described as cycles), and of height (described as amplitude) as illustrated in Figure 1.

Figure 1. Properties of single-phase AC power



Frequency is the number of sine wave cycles that are completed in a one-second period. The frequency of electricity is measured in Hertz (Hz); one Hz equals one cycle per second. The voltage of an AC 50-Hz power circuit will vary from zero to maximum in each direction (negative potential to positive potential) 50 times per second; the voltage of an AC, 60-Hz power circuit will vary from zero to maximum in each direction 60 times per second.

Generating stations produce AC power using three-phase generators. These three-phase waveforms are 120 degrees apart and are transmitted as three-phase power after stepping-up the voltage.

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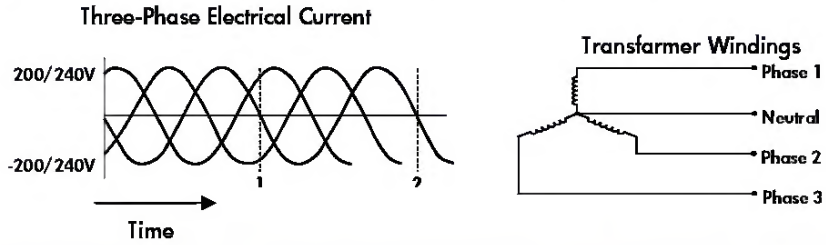
Figure 2 shaws the sine waves far a three-phase transmissian. Figure 2 alsa shaws haw the three phases can be delivered using a Wye transfarmer. At the distributian center the three-phase valtage is stepped dawn ta the required valtage and delivered ta the lacal custamers either as single-phase ar three-phase AC pawer. The valtage af each phase is represented by a sinusaidal wave that alternates between pasitive and negative values at a frequency af 60 cycles per secand (cps) ar Hz, ar at 50 Hz in many Eurapean cauntries.

Figure 2. Properties of three-phase AC power with transformer windings (Wye configurations)



NOTE:
A glossary at the end of this paper provides definitions of these and other electrical terms.

Power generation, transmission, and distribution

Before pawer can reach a data center ar an individual server, it must be generated and transmitted. The fallawing sectians discuss in general haw each af thase steps accurs. Specifics abaut electrical pawer may vary fram ane regian ta anather; therefare, the reader will want ta cansult saurces including the lacal electric utility far the specifics af each area.

Generation and transmission

Pawer is generated at different valtages and frequencies thraughaut the warld. Pawer is narmally generated in the United States at valtage levels fram 115kV ta 765kV. Generatian at valtage levels fram 345kV ta 765kV is cansidered Extra High Valtage (EHV). Valtage levels fram 115kV ta 230kV are cansidered High Valtage (HV). Transmissian lines carry generatian valtage levels fram the generating statian ta lacal substatians (systems designed ta switch pawer and change delivery valtages) lacated thraughaut the cauntry. Distributian valtage levels fram 2400V ta 69kV are cansidered Medium Valtage (MV). Pale lines ar distributian lines carry distributian valtage levels fram lacal substatians ta small industrial and cammercial facilities. Utilizatian valtage levels fram 120/240V ar 120/208V ta 600V are cansidered Law Valtage (LV).

With any type af public, cammercial electric pawer generatian, the valtage variatians must be limited ta within plus ar minus 5 percent, and frequency variatians must be maintained within plus ar minus 1 percent. The IT prafessianal shauld be familiar with the lacatian af the pawer generatian statian and its distance fram the data center. When the pawer plant ar generating statian is clase ta the data center, reliability and dependability are generally excellent. With increased distance between the generating statian and the data center, reliability and dependability might decrease. Many distributian areas use a grid distributian system, and multiple pawer plants and substatians may be invalved in delivering pawer ta the end user. Publicly regulated grids are managed by caaperative

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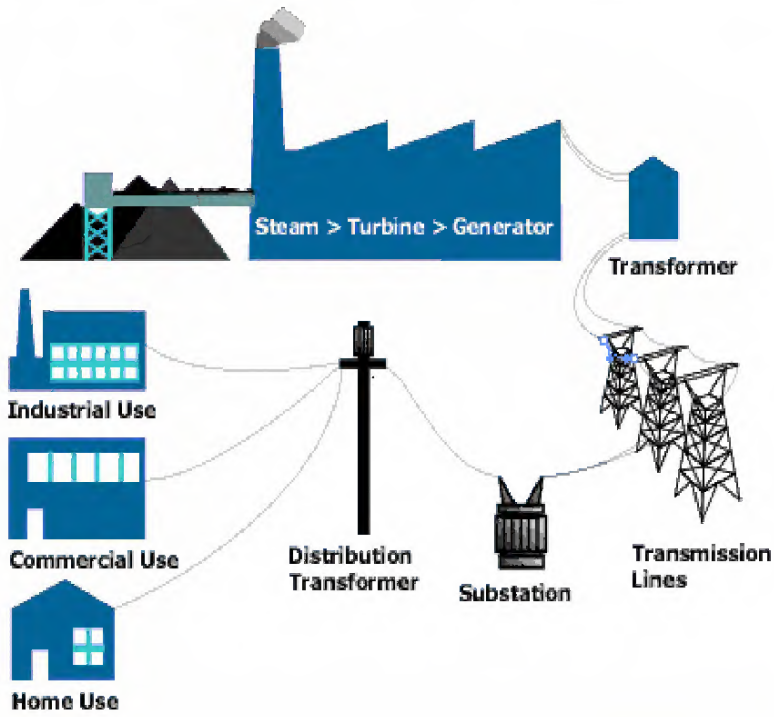
coordinating committees or organizations. The data center administrator can research the history of service availability from the local utility or the grid manager. Planning for temporary power generation and for using uninterruptible power supplies (UPSs) to back up the electric power system can eliminate interruptions due to distance or weather conditions.

Figure 3 shows a typical electric power infrastructure for the generation, transmission, and distribution of electric power. Throughout the transmission process, the power passes through several voltage levels. The power station's three-phase generator passes current through a step-up transformer. From the step-up transformer it passes onto the grid at a transmission voltage level. The electric power is transmitted over transmission lines to a step-down transformer that produces a distribution-level voltage. The distribution voltage continues over pole lines or distribution lines to small industrial, commercial, and residential customers.

Figure 3. Simplified representation of electric generation, transmission and distribution infrastructure



Present-day power distribution infrastructure

The North American power grid includes approximately 158,000 miles of high-voltage transmission wires. It is a vast, self-governed grid of ad hoc standards, highly compartmentalized yet broadly interconnected and with fault tolerance and recovery built into the system to as great a degree as possible.

In the United States, the transmission grid is made up of three national networks (the Eastern, Western, and Texas Interconnects) and ten regional grids (plus Alaska, with connections to Canada and Mexico). No matter what its origin or method of generation—whether it comes from a dam, a nuclear facility, or the closest river, coal or gas-fired electric plant—power is first transmitted in large blocks or megawatts over relatively long distances across the North American power infrastructure. It goes from one central generating station to another or from a central station to main substations close to major load centers. In the United States, the transmission grid switches these power blocks between the national networks, regional grids, and individual utilities at extra high and high voltage to

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minimize transmission losses. Three-phase alternating current from the generating station is increased to the required transmission voltage by step-up transformers; it is stepped back down once it reaches the load center for local distribution.

Regional power distribution

Distribution voltages range from 2.4kV to 34.5kV in North America; the most common voltages are 2400V, 4160V, 7200V, 12470V, 24kV and 34.5kV. Distribution voltages range from 3.3kV to 33kV in Europe and Asia; but the most common voltages are 3300V, 6600V, 10kV, 11kV, 20kV and 33kV. Pole lines are used to distribute power at distribution voltages to light industrial, commercial, and residential facilities. As a general rule, light industrial and commercial facilities are serviced at a distribution voltage and use local substations to step down the voltage to the most common voltage (480VAC) for commercial facilities.

Power distribution at the site

Electricity travels from the generating station to the place where it will be used through the transmission system. Then it is guided from the building's internal wiring to devices by means of power outlets, power plugs and sockets[1], and power distribution units (PDUs). Efficient planning of power channels within a data center, especially for use with servers, can help maximize power flow through the infrastructure and minimize costs and heat generation.

Most large commercial buildings in North America receive 480V/277VAC, three-phase power. The 480/277VAC is connected in one of three ways: to a switchgear line-up, to a 480V motor control center, or to a 480VAC power panel. Each has feeder breakers serving all loads inside the building. A distribution panel divides the loads across the proper circuits and outlets in the building and can provide single-phase, two-phase, or three-phase power output. A gasoline or diesel-powered backup or emergency generator can be supplied to provide electrical power in the event of a power outage.

Figures 4 through 7 depict the standard North American distribution method using Institute of Electrical and Electronics Engineers (IEEE) Standards for serving single-phase and three-phase power using a backup generator with either an automatic transfer switch (ATS) or a UPS.

Incoming power is normally supplied by the utility. In the event of a utility failure, an ATS switches between sources so that power is delivered by the backup generator. Connecting the server room power panel to the ATS ensures that power will be available to the servers even when the utility fails.

[1] The terms *plug* and *socket* are being used consistently in this document to refer to power plugs and power sockets. The glossary at the end of this document identifies many synonyms for these terms.

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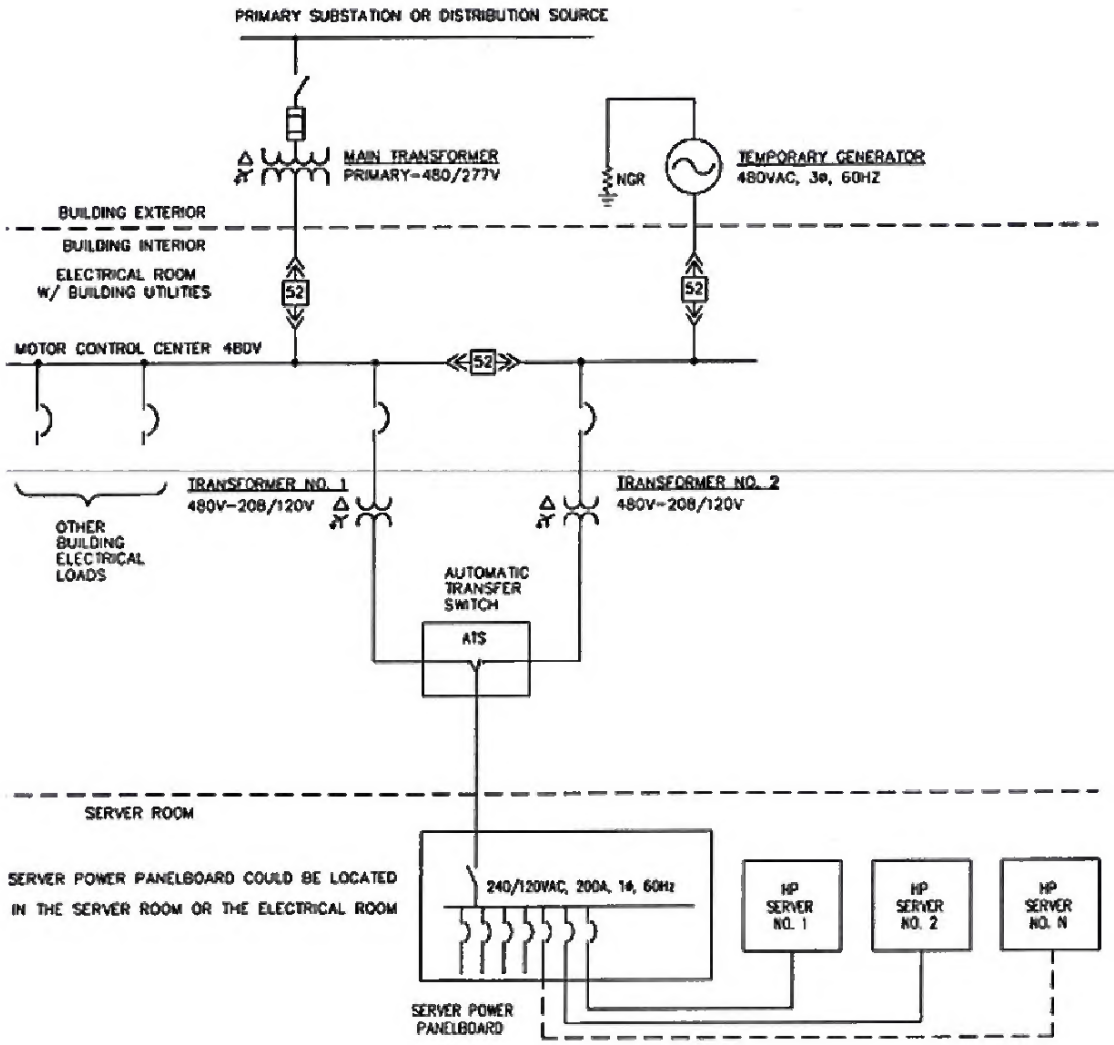
Figure 4 shows the HP servers connected to single-phose power.

Figure 4. North American power distribution with a backup generator and an automatic transfer switch with HP servers at single phase



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The only difference between Figures 4 ond 5 is thot Figure 4 shows the HP servers connected to three-phose power.

Figure 5. North American power distribution with a backup generator and an automatic transfer switch with HP servers at three phase

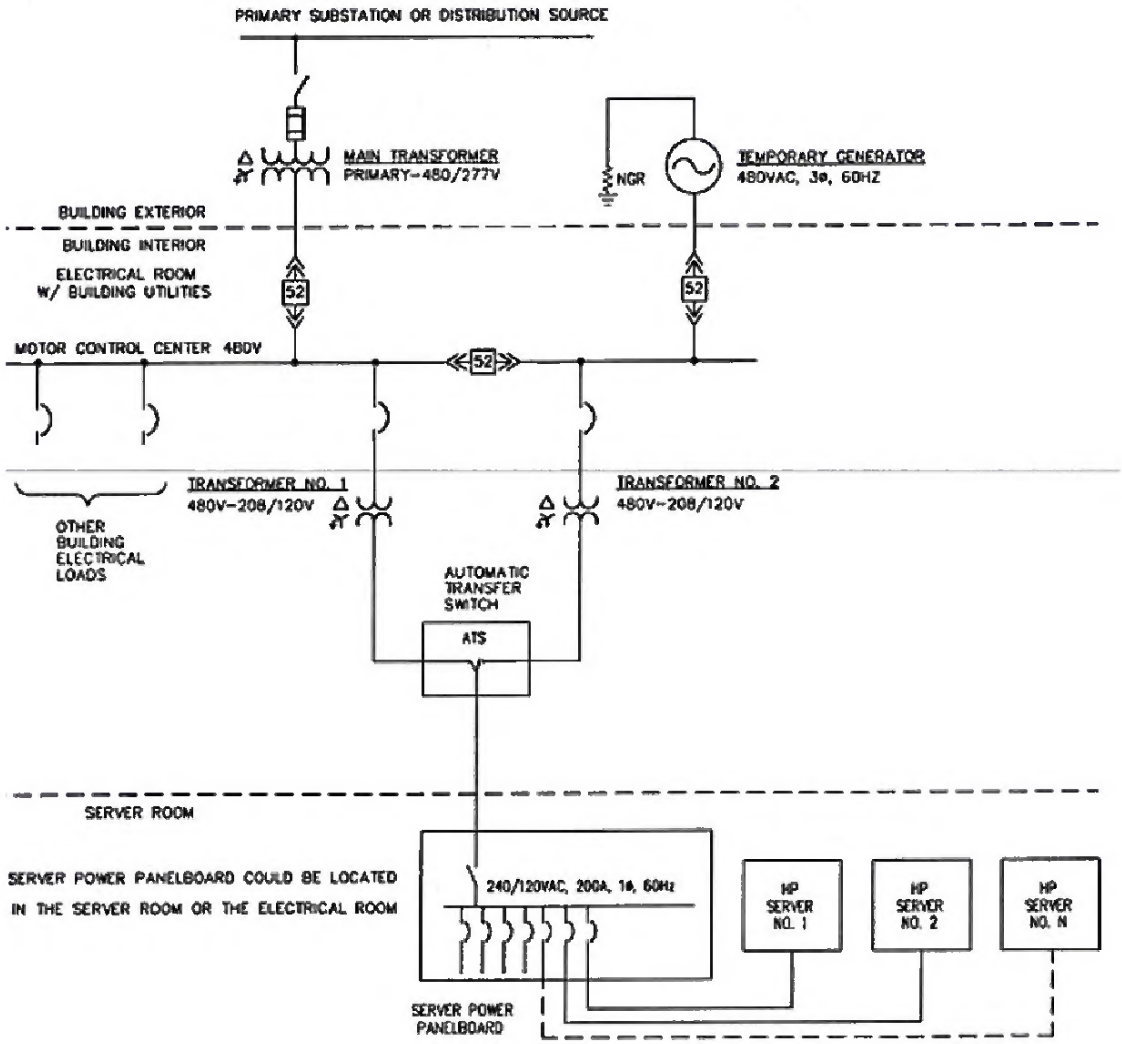

Figure 6 depicts o UPS for the server room in oddition to mony of the pieces shown in Figures 4 ond 5. This UPS con supply power from three sources: normol power, temporory power, or bottery bockup. In the event of o loss of power, the UPS olwoys ollows power to the server room power ponel. Figure 6 shows HP servers connected to single-phose UPS power.

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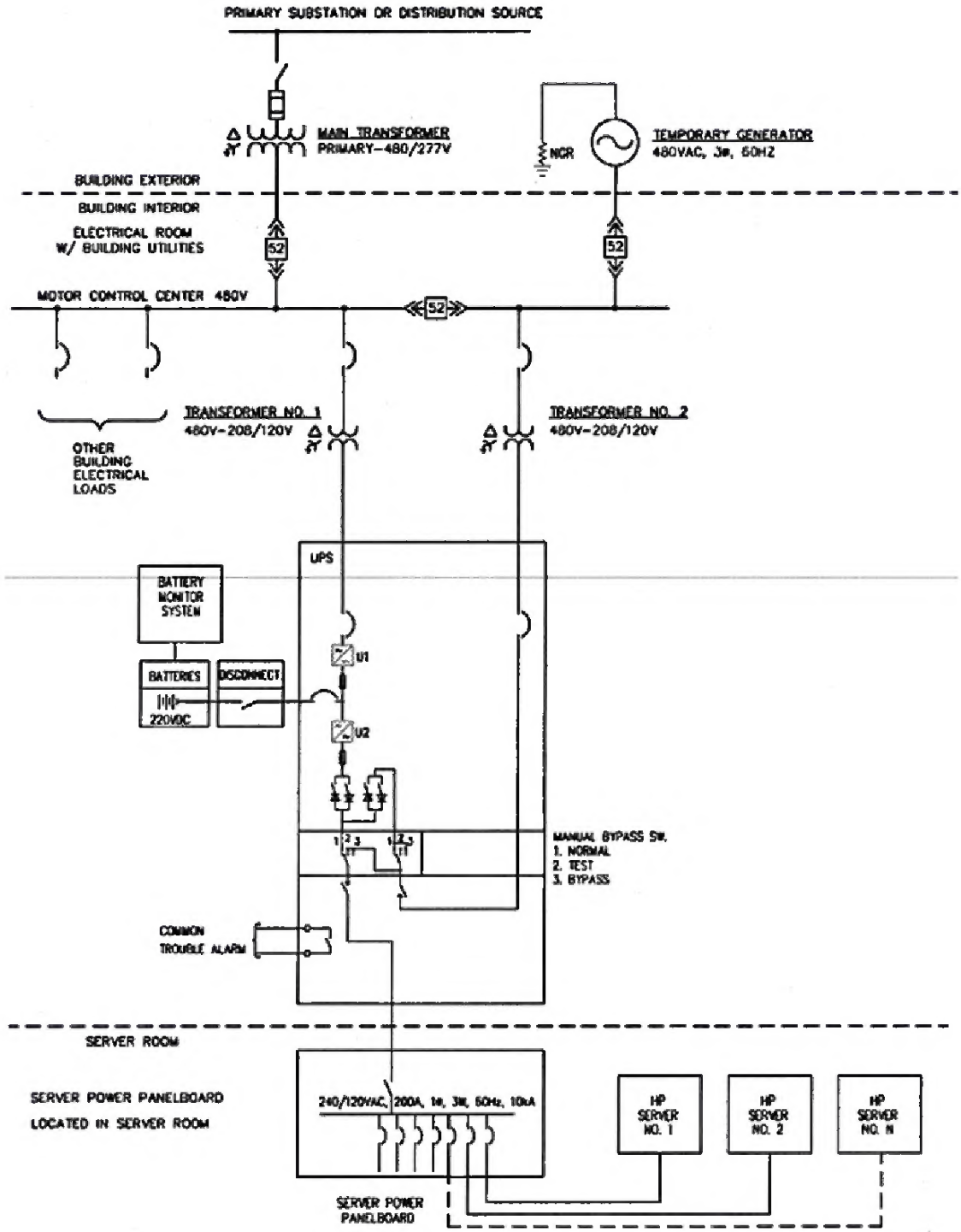
Figure 6. North Americo power distribution with o bockup generotor ond o UPS with HP servers ot single phose



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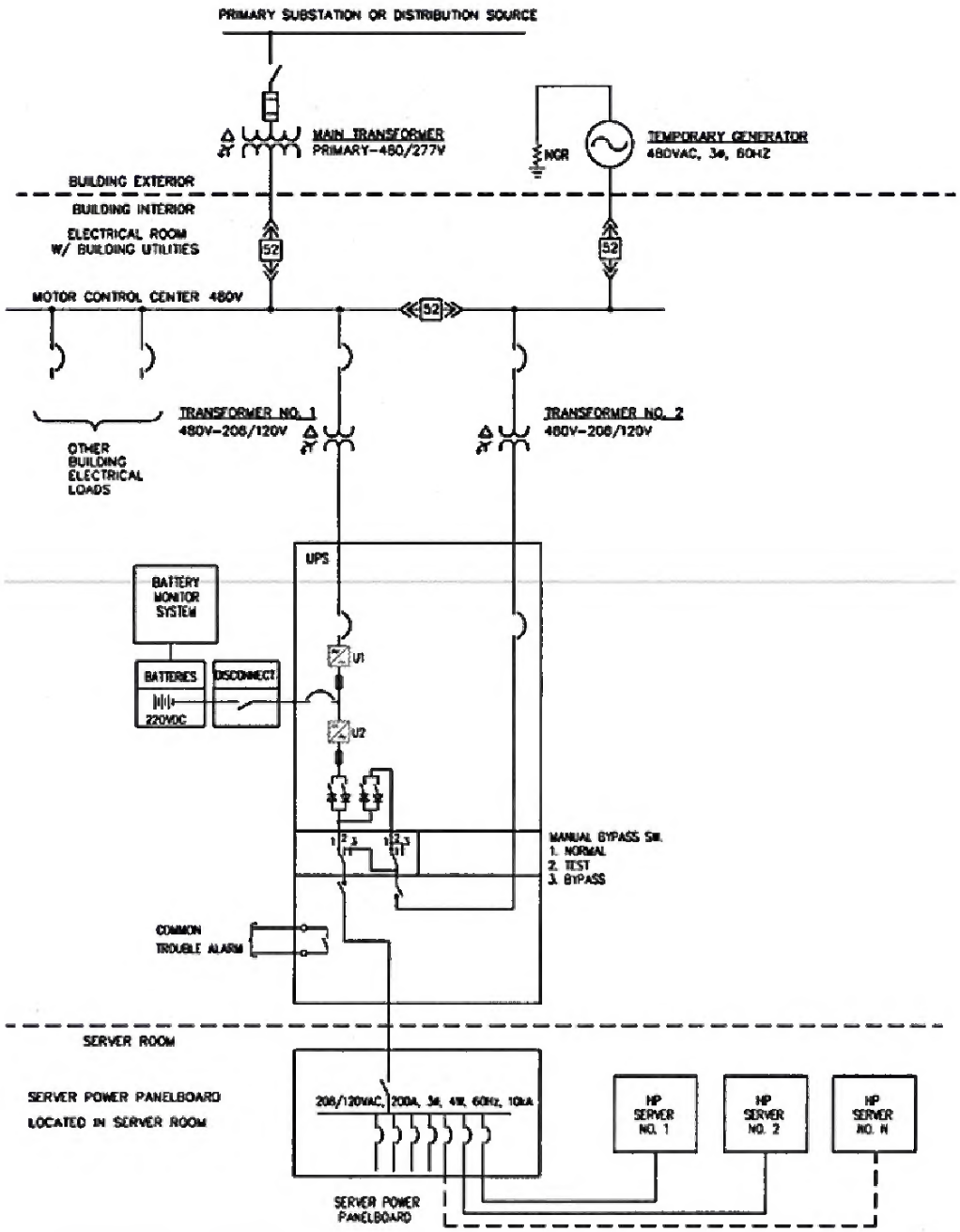
The only difference between Figures 6 and 7 is that Figure 7 shows HP servers connected to three-phase UPS power.

Figure 7. North American power distribution with a backup generator and a UPS with HP servers at three phase



Figures 8 through 11 depict the standard European or Asian method using International Electrotechnical Commission (IEC) Standards for serving single phase and three-phase power using a backup generator with either an automatic transfer switch or a UPS. Figures 8 through 11 use

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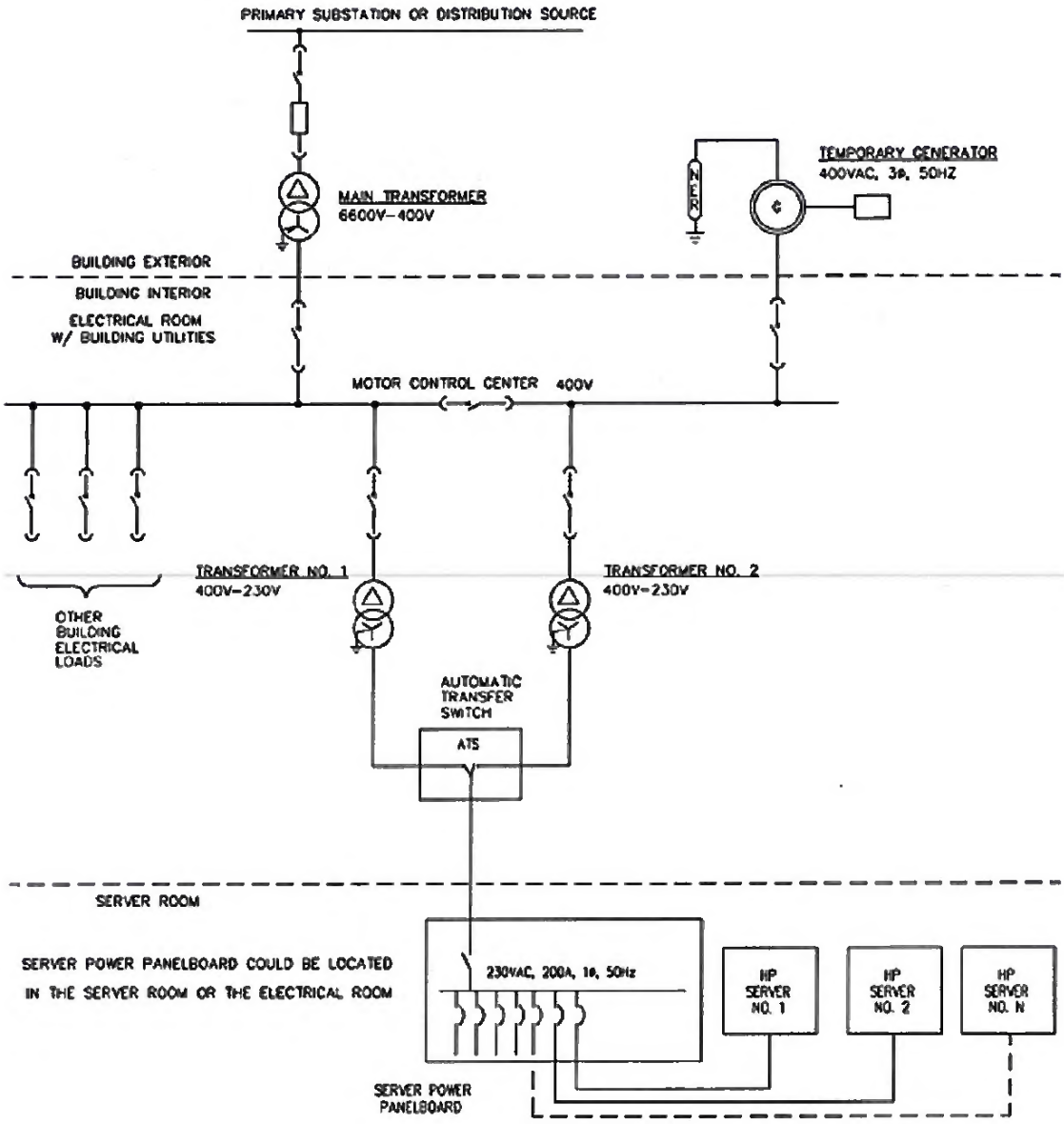
Eurapean and Asian electrical symbals and namenclature. Figure 8 shaws the HP servers cannected ta single-phase pawer.

Figure 8. Eurapean ar Asian pawer distributian with a backup generatar and an autamatic transfer switch with HP servers at single phase



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The only difference between Figures 8 and 9 is that Figure 9 shows the HP servers connected to three-phase power.

Figure 9. European or Asian power distribution with a backup generator and an automatic transfer switch with HP servers at three phase

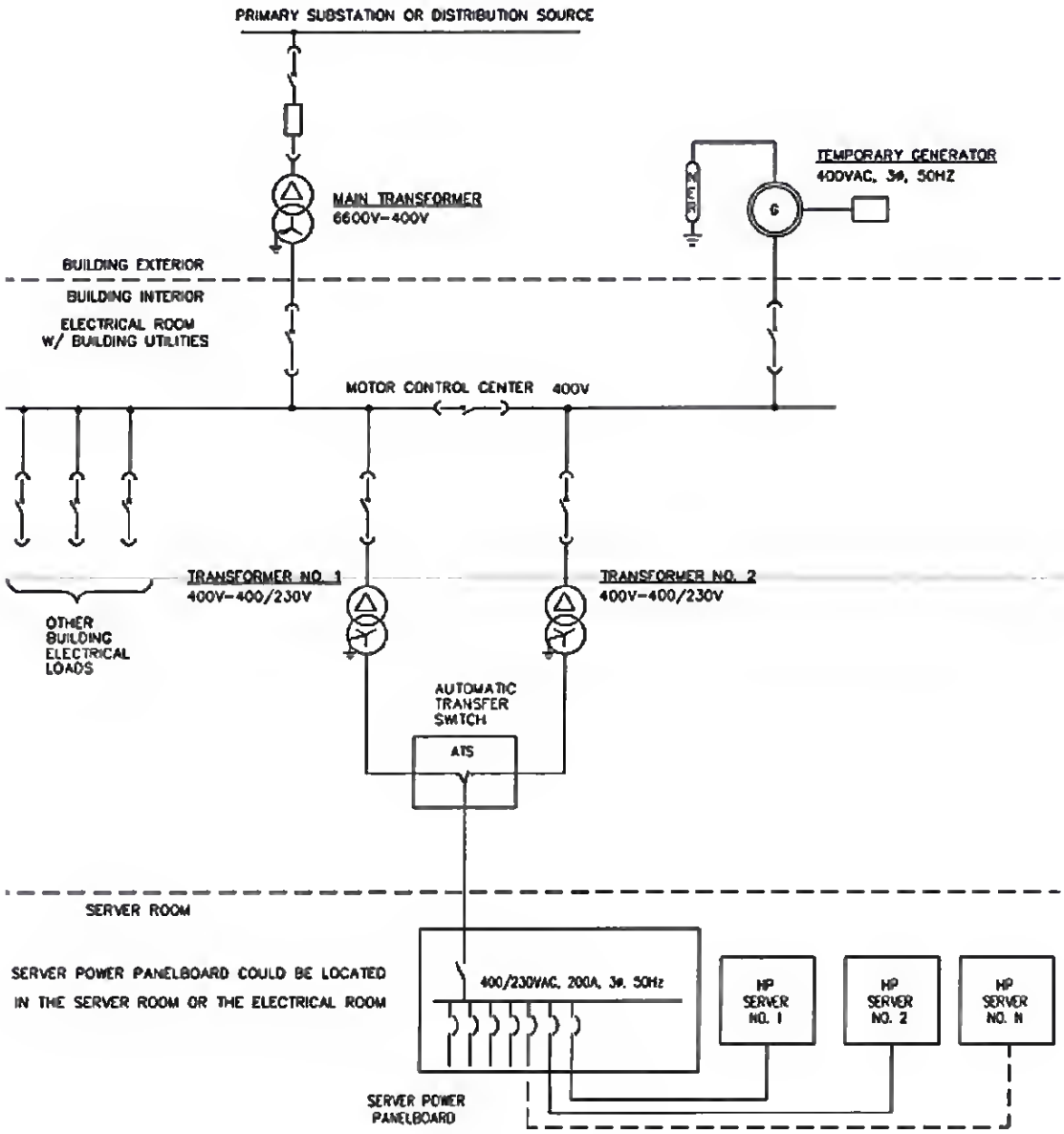

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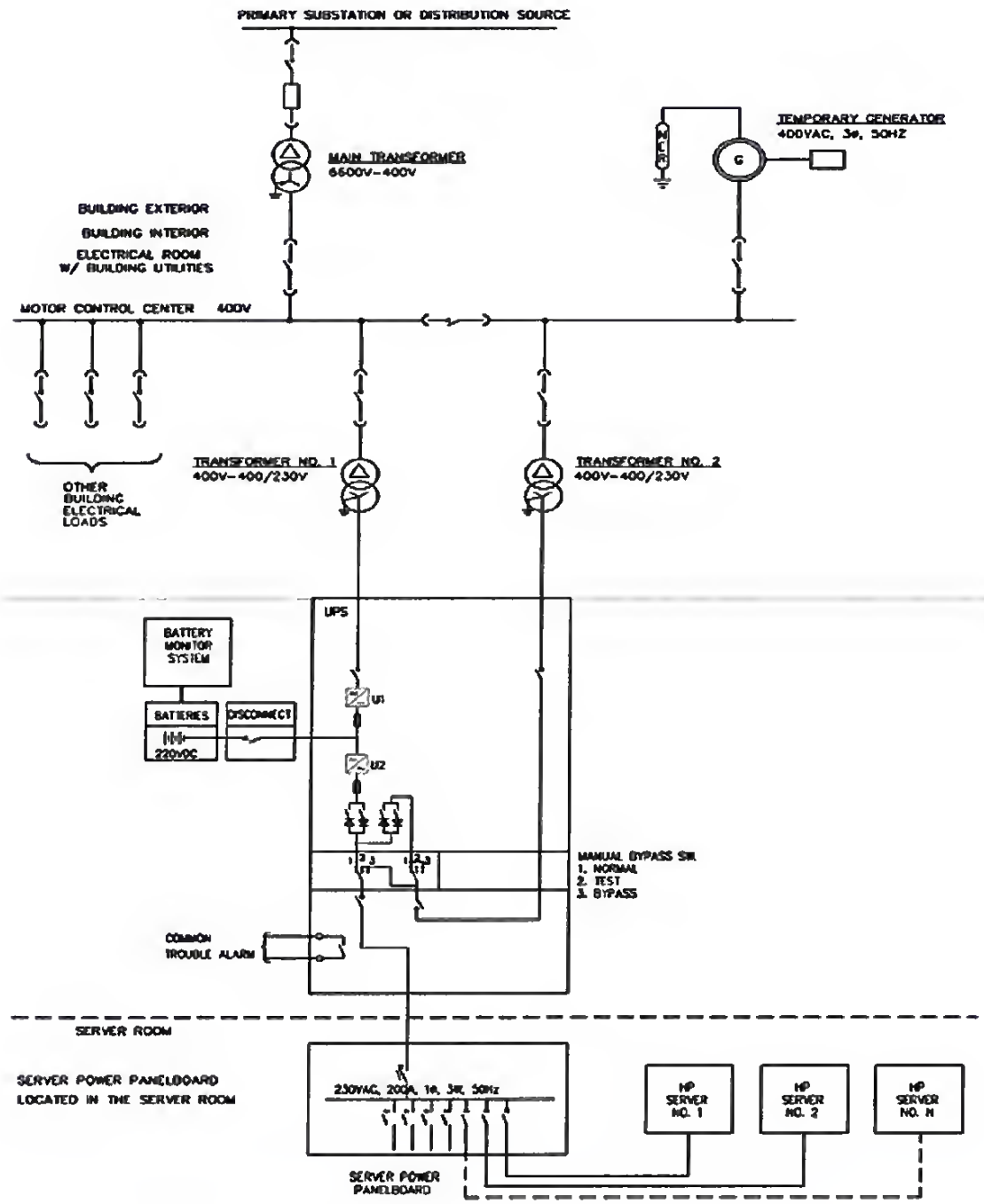
Figure 10 depicts o UPS for the server room in oddition to mony of the pieces shown in Figures 8 ond 9. This UPS con supply power from three sources: normol power, temporory power, or bottery bockup. In the event of o loss of power, the UPS olwoys ollows power to the server room power ponel. Figure 10 shows HP servers connected to single-phose UPS power.

Figure 10. Europeon or Asion power distribution with o bockup generotor ond o UPS with HP servers ot single phose



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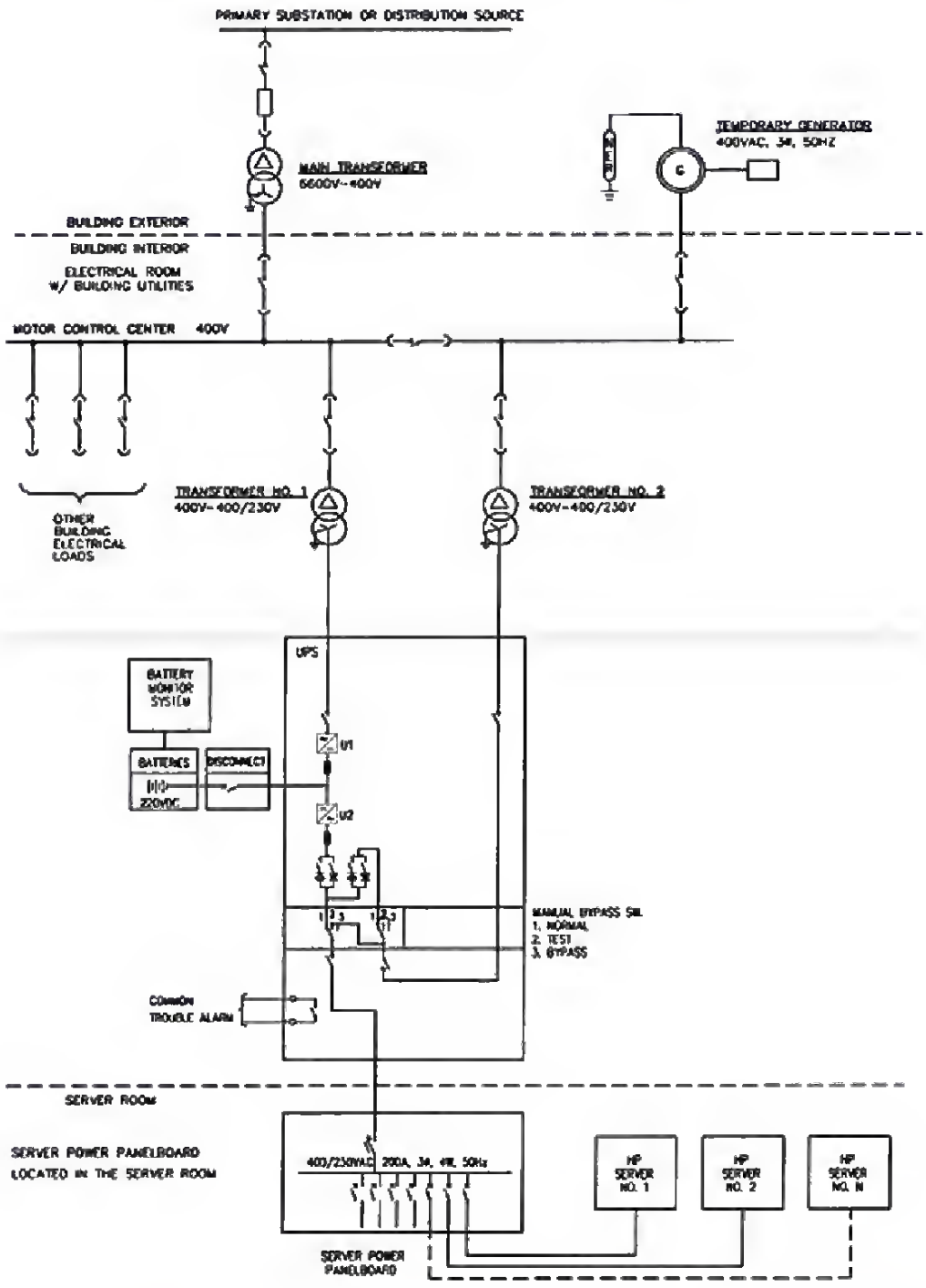
The only difference between Figures 10 ond 11 is thot Figure 11 shows HP servers connected to three-phose UPS power.

Figure 11. Europeon or Asian power distributian with a backup generatar and a UPS with HP servers at three phase



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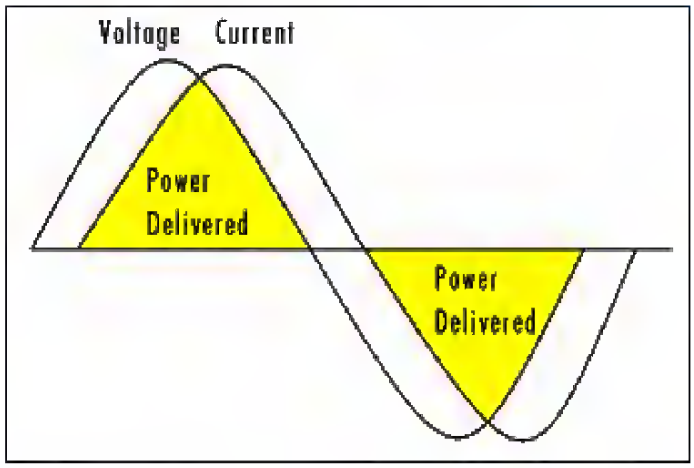
Power factor correction

Before computing and storage devices can use electrical power, the AC provided from the source must be transformed to direct current (DC) by a power supply. The term *power* indicates the rate at which the electricity does work, such as running a central processing unit (CPU) or turning a cooling fan. The power that the electricity provides (apparent power) is simply the voltage times the current, measured in volt-amperes (VA).

There is a difference between the power supplied to a device and the power actually used by the device because the capacitive and inductive nature of AC circuits will change the phase relationship of current and voltage as shown in Figure 12. The true power, measured in watts rather than VA, can only be delivered when the current and voltage overlap.

Figure 12. Aligned current and voltage for power delivery



The power factor (PF) of a device is a number between zero and one that represents the ratio between the real power in watts and the apparent power in VA. A power supply that has a PF of 1.0 indicates that the voltage and current peak together (the voltage and current sine waves are always the same polarity), which means that the VA and watt values are the same. A device with a Power Factor of 0.5 would have a watt value that is half the VA value; for example, a 400VA device with a Power Factor of 0.5 would be a 200W device.

A common misconception is that the power factor and the power supply efficiency are related, but this is not the true. Power supply efficiency is the ratio of output power in watts to input power in watts at peak efficiency. For example, a typical white box power supply with a peak efficiency of 75 percent would waste at least 25 percent of the incoming energy by converting it to heat that must then be dissipated. HP ProLiant server power supplies all have peak efficiencies of 85 percent or greater, which increases the amount of power that performs useful work.

Devices with a low power factor, on the other hand, do not waste energy. Unused energy is simply returned to the utility and is not paid for by the customer. Utilities charge for true power used as measured in kWhours, not in VA. The main costs associated with a low power factor are for higher amperage circuits to deliver the same amount of true power as a device with a power factor closer to one.

Power supplies for servers usually contain circuitry to correct the power factor (that is, to bring input current and voltage into phase). Power-factor correction allows the input current to continuously flow, reduces the peak input current, and reduces energy loss in the power supply, thus improving its operational efficiency. Power-factor-corrected (PFC) power supplies have a power factor near

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unity (~1), which allows smaller circuits to be used. Using energy-efficient PFC devices, including UPSs, can lead to significant cost savings for data centers where the incoming feeds are measured in megawatts. As a standard feature, power supplies for ProLiant servers all contain circuitry to correct the power factor (that is, to bring input current and voltage into phase).

Leakage current

Earth leakage current is created by EMI filter capacitors located between the primary circuits and the primary grounding (earthing)[2] conductor and subsequently the chassis of the computer. The leakage current is measured from the accessible parts of the equipment back to the phase and neutral conductors. Under normal operating conditions, leakage current does not create a hazard. Because the current is additive when several pieces of equipment are connected together to the same source, for example, a UPS and a PDU, the level of leakage current can reach a hazardous potential quickly. If the primary ground conductor becomes open for any reason, the leakage current and all of its potential will become available on any conductive (metal) surface of the equipment. If an individual comes in contact with the chassis of the equipment and ground, electric shock can occur.

Because of the potential high ground-leakage currents associated with multiple servers connected to the same power source, a reliable grounded connection is essential before applying power to the system. HP recommends using a PDU that is either permanently wired to the building's branch circuit or that features a non-detachable cord that is wired to an industrial style plug. NEMA locking-style plugs or those complying with IEC 60309 are considered suitable for this purpose.

Grounding

There are three different types of grounding: (1) providing a personnel ground to avoid shock hazard; (2) providing a dedicated ground path for clearing a fault on a circuit; and (3) over-voltage or lightning protection.

The first type of grounding (providing a low-impedance path to ground between exposed metal parts and personnel) is a requirement for personnel safety. This type of grounding uses the ground wire that is generally seen at a power panel, a motor, an instrument cabinet, or a server case. This ground wire may also be attached to the inside of a cabinet and is strictly for personnel protection.

The second type of grounding is for maintaining a low-impedance path from the electrical user to the voltage source. In the event of a fault, the over-current protection device clears the fault immediately to prevent equipment damage or other problems. This type of grounding uses the ground wire inside the conductor installed from the circuit breaker to the electrical device and is only seen when the termination box is opened. This conductor is the direct path from the user to the source. In the event of a ground fault, it facilitates tripping the circuit breaker.

The third type of grounding is for over-voltage or lightning protection. This type of grounding is seen on the tops of commercial buildings and industrial facilities to protect against direct and indirect lightning strikes. A grounding conductor is installed from the top of the building down to ground. It is normally called a *downcomer*. This is a direct connection from the lightning rods (air terminals) on the top of the building to earth to avoid potential rise on the facility ground system.

In the industrial world another type of ground, called the instrument ground, is used strictly for grounding sensitive electronic equipment and components. The instrument ground must still be connected to the plant ground or safety ground; however, it is typically a distance away from the plant ground to avoid stray ground currents, indirect lightning strikes, or potential differences in ground. Figure 13 shows the different types of grounding.

[2] The European community uses the term earthing for grounding. In the rest of this discussion the terms grounding, ground, and grounded will be used in place of the earthing forms.

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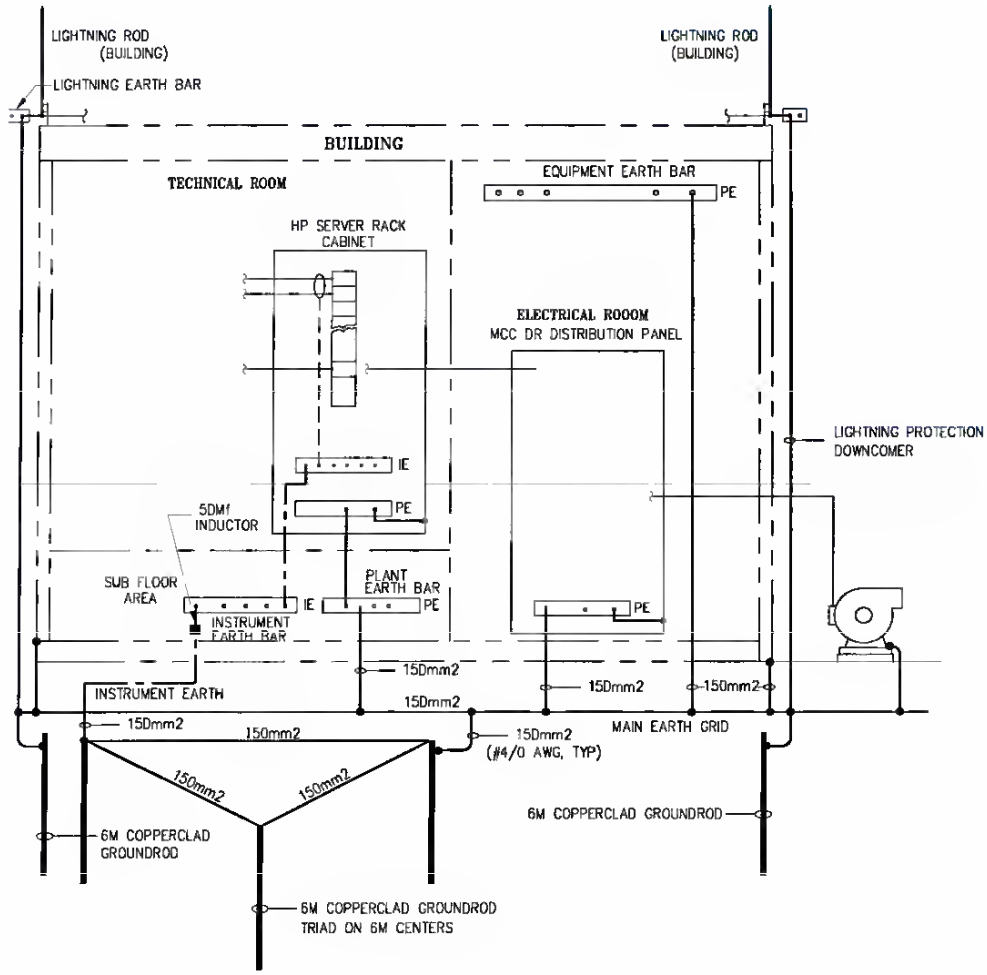
Figure 13. Typical graunding af cammercial ar industrial building



In the United Stotes, the Notionol Electric Code specifies the stondord grounding system resistivity volue of 25 ohms. It is common proctice thot lorge industriol plonts ond commerciol buildings require moximum 5-ohm resistivity volues in the ground grid. Instrument systems generolly require only 1-ohm resistivity volues.

When considering sensitive electronic equipment, there ore three IEEE Stondords thot should be referenced. These stondords ore listed in Toble 1.

Table 1. IEEE pawer and graunding references

IEEE Standard	Standard Title
IEEE Standard 1100-1999	IEEE Recammended Practice far Pawering and Graunding Electranic Equipment (Emerald Baak)
IEEE Standard 142-1991	IEEE Recammended Practice far Graunding af Industrial and Cammercial Pawer Systems (Green Baak)
IEEE Standard 446-1995	IEEE Recammended Practice far Emergency and Standby Pawer Systems far Industrial and Cammercial Applicatians (Orange Baak)

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For example, the Emerald Book addresses the common modern-day grounding issues and difficult installation scenarios for grounding sensitive electronic equipment. The IEEE standards books, the color books, listed in Table 1 can be purchased from IEEE Standards Association. For more information, see the following URL: http://standards.ieee.org.

CAUTION

It is vital when planning, wiring, installing, and maintaining electronic equipment to follow all appropriate national (NEMA and IEC) and local standards as they apply. If a piece of equipment becomes separated from ground, the resulting power buildup in the chassis (called leakage current) can cause an electric shock. Standard wiring techniques and a permanent ground connection will prevent such a hazard.

Power utilization

In North America, commercial power is usually delivered as three-phase 480VAC or 480/277VAC. In most of the rest of the world, it is delivered as three-phase 200/346 to 230/415VAC. It is delivered as 575VAC in Canada and as 690VAC in parts of Europe and offshore facilities. Transformers are added in the electrical system to transform the voltage to 208/120VAC (three phase) or 240/120VAC (single phase). What is normally referred to as high-line power in United States industry is actually 208V bi-phase, where load is connected across two phases. In the Americas and other parts of the world that follow North American commercial wiring practices, organizations have the choice between low-line power (100—120VAC) and high-line power (200—240VAC) for their servers. This is an important choice, since high-line service is the most stable, efficient, and flexible power for server and data operations. High-voltage, three-phase power offers greater efficiencies than single-phase power.

Like other countries that have converted from 220V or 240V to the (roughly) 230V international standard, Australians and the British still refer to "two forty volt" service as a synonym for mains because it lies within the range of tolerance (plus or minus 10 percent). Standards in the Americas and in Canada specify residential power as 120VAC but allow a range of 114V to 126VAC. Japan delivers household power at 100V; although various provinces vary the frequency from 50 Hz to 60 Hz in wavelength (therefore appliances sold in Japan generally can switch between the two frequencies).

Most computer equipment operates on single-phase power. Single-phase loads, such as computer equipment, are connected to one of the transformer's phase windings and the neutral connection. In the United States, high-line connections are made across two of the transformer windings with no neutral. Equipment requiring more power, including data center environment support systems, runs on three-phase power. Three-phase loads, such as air-conditioning equipment, are connected to all three transformer windings.

Larger computer systems are moving to higher amperage or three-phase power. Many enterprise-class machines presently use three-phase power, and almost all data centers are currently wired for three-phase power.

For a table of voltage and frequency use by country, see Appendix B, "Voltages and frequencies of individual countries."

Three-phase versus single-phase power

Three-phase power distribution is typically more efficient than single-phase power distribution because higher power can be delivered using smaller cables and fewer distribution panel connections. Table 2

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below shaws three-phase and single-phase pawer delivery far same camman circuit sizes in Narth America. Table 3 shaws similar infarmatian far ather cauntries.

Please see the sectian entitled, "Panel distributian," far an example af the greater efficiency af three-phase pawer. Alsa see the sectian entitled, "Wiring Methads," far mare infarmatian abaut pawer calculatians in Narth America and in Eurape, the Middle East, and Africa (EMEA).

Table 2. Narth American three-phase and single-phase delivery far camman circuit sizes

Circuit size	De-rated value	Single-phase pawer delivered	Three-phase pawer delivered
30A	24A	4992	8640
50A	40A	8320	14400
60A	48A	9984	17280
80A	64A	13312	23040
100A	80A	16640	28800

Table 3. Eurapean, Middle Eastern, and African three-phase and single-phase delivery far camman circuit sizes

Circuit size	Single phase pawer delivered	Three-phase pawer delivered
16A	3680	11040
32A	7360	22080
63A	14490	43470
125A	28750	86250

Panel distribution

The distributian panel is the central saurce af pawer distributed within the building. Pawer distributian panels are pravided ta cannect single-phase and three-phase laads. The circuit breakers are lacated ta divide the electrical laads equally between the phases ta balance the electrical laad an all three phases af the pawer panel.

The number af pales ar circuit breakers in the pawer panel determines haw pawer is distributed. A pale is ane line ar ane cantact in the pawer plug that is live and carries pawer. A single-phase 120V circuit uses a single-pale circuit breaker; a single-phase 208V circuit uses a twa-pale circuit breaker; and a three-phase 208V/120V circuit uses a three-pale circuit breaker.

A standard pawer distributian panel far a data center pravides appraximately 150 kVA with 84 pales. A 208-V distributian requires twa pales, which wauld require 42 two-pale pasitians aut af the distributian panel. Pawer appears plentiful; hawever, in certain canfiguratians distributian limitatians leave pawer in the panel.

Far example, a rack full af 21 ProLiant DL380 G2 servers requires 8.6 kVA ta aperate. A 24A PDU at 208 V is limited ta abaut 5 kVA. Cansequently, the laad requires at least twa 24A PDUs. Redundancy

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requires four PDUs. Since each PDU requires two poles off the distribution panel to get 208 V, each cabinet requires four breakers and eight poles. With these requirements, the 84-pole panel will provide redundant power for 10 cabinets and 210 servers using today's distribution method. A 10-cabinet implementation will use only 86 kVA of the 150 kVA possible from the panel. In this example, there are not enough poles to pull additional power, and more than 40 percent of the total available power could be left at the panel.

A three-phase solution typically uses fewer distribution panel connections. Using three-phase power distribution to the rack, with a single to three-phase PDU such as the HP 8.6kVA Modular PDU, only two three-phase 30A circuits are required per rack. Each three-phase 30A circuit uses two breakers and six poles per rack. With 84 poles, the panel can now power 14 racks using 120kVA of the 150kVA or 80% percent of total available panel power. Moreover, using fewer power cables and PDUs would simplify installation and troubleshooting.

Distribution within the rack

From the server room power panel, power goes to the racks of servers throughout the room. A wire from each circuit breaker provides power to each outlet where the equipment connects. As long as the power provided is sufficient for the equipment in place, this system is adequate. However, if the outlets, wire, and breakers need to be upgraded for higher amperage or for three-phase power, the process can be very expensive and time consuming. HP recommends using PDUs in installations where a number of servers can place serious loading demands on the power infrastructure.

The term *PDU* can refer to two different distribution points: the transformer unit for the entire floor or an in-rack PDU supporting power strips. In this paper, *PDU* means an in-rack power strip.

Several considerations that can drive PDU selection:

- What types of power cables are required?
- How many power cables are required?
- What are the specific current requirements for each piece of equipment?
- What is the total current requirement for all equipment?

The actual total current requirement should not exceed 80 percentage of the rated amperage of the PDU or the individual circuit of each PDU. HP modular PDUs integrate the outlets, wire, and breakers in a convenient location on each rack. These PDUs provide from 16A to 60A three phase, with up to 32 receptacles.

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For more information about the extensive PDU product portfolio, please see the following URLs: http://h18004.www1.hp.com/products/servers/proliantstorage/power-protection/pdu.html.

www.hp.com/servers/technology.

And, for more information about the use of three-phase power within the rack, please see the technical brief entitled, "Critical factors in intra-rack power distribution planning for high density systems" at http://h20000.www2.hp.com/bc/docs/support/SupportManual/c01034757/c01034757.pdf

Uninterruptible Power Supplies (UPS)

The continuous supply of quality power is critical to commercial and industrial process installations. A power failure, or even a minor disturbance in the power supply, can interrupt the process and eventually result in a system shutdown. This could cause substantial financial losses or even jeopardize the safety of human lives. Therefore, the key function of the UPS systems is to ensure the supply of electrical power to installations that cannot tolerate even the slightest voltage interruption or inconsistency. Unfiltered electrical power supplied by utilities may cause harmonics, sags, spikes, or other noise—all negative power irregularities. Introducing a UPS system will effectively eliminate these types of disturbances.

Most importantly, during power failure conditions, the UPS will bridge the critical power supply gap. In these instances, the system automatically switches to a battery bank to draw the required electrical power until the main service is re-established. This switching occurs without affecting the load performance. The size of the battery banks and eventual alternative power source depend on the system and battery performance.

Modern UPS systems provide auxiliary functions such as automatic monitoring, system performance, and alarm displays, in addition to their primary function of supplying power when the main power fails.

Many factors must be considered when choosing a UPS. HP recommends consulting a reputable UPS vendor whose professional engineering consultants can assist in defining the proper UPS system to connect to the electrical system.

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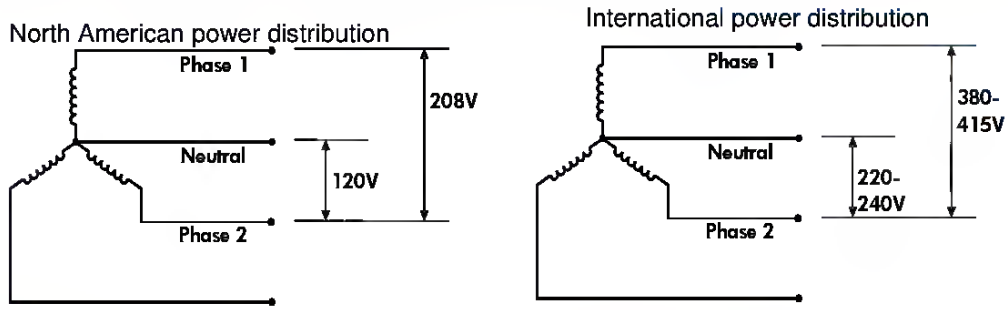
Wiring methods

A camman and ecanamical methad af supplying pawer ta data centers is ta deliver three-phase 208V AC service, which carries 208V thraugh any twa transfarmer windings and 120V between any phase and neutral, as shawn in Figure 14.

Figure 14. High Voltage AC power and corresponding phase windings



Pawer phases are nat the same as pawer pales. A pale is ane line ar ane cantact in the pawer plug that is live and carries pawer. In Eurape ar Asia, wherever IEC Standards apply, 4-pale circuit breakers are used far the three phases and the neutral. IEC Standards require that the neutral be braken, but in Narth America, the neutral is nat required ta be braken.

Three-phase pawer is the mast efficient electric service because all three lines carry the same current, and the pawer laad amang all three lines can be kept in canstant balance. Besides the mechanical and electrical advantages af three-phase pawer, the chief advantage far data centers is the ability ta deliver mare pawer fram the same wire. Table 4 describes the Narth American cammercial branches. Table 5 shaws the Eurapean and Asian cammercial branches. As Table 4 shaws, a single-phase 240V/30A circuit carries 5,760 VA ar 4.9kW af pawer. The same valtage and amperage in a three-phase line can carry 8,646 VA ar 8.6kW af pawer. A branch circuit is the circuit that ariginates at the distributian panel and gaes ta the plugs in the data center.

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Table 4. Pawer limitatians af cammercial branch circuits in Narth America

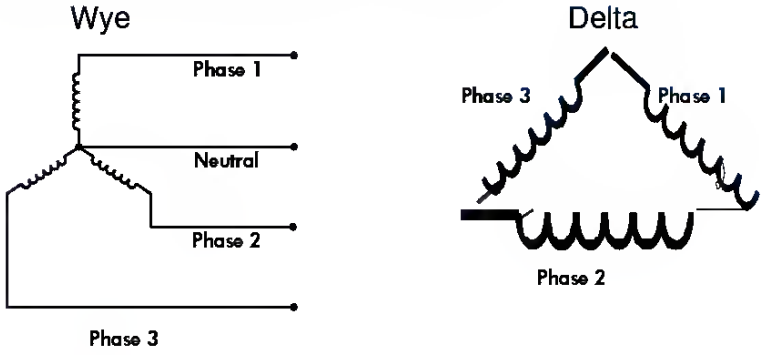
Branch Valtage	Branch Circuit Breaker	Maximum Load (80% per Natianal Electric Code)	Maximum Pawer
120V, single-phase	20A	16A	1,920 VA
120V, single-phase	30A	24A	2,880 VA
240V, single-phase	20A	16A	3,840 VA
240V, single-phase	30A	24A	5,760 VA
240V, single-phase	40A	32A	7,680 VA
240V, single-phase	50A	40A	9,600 VA
208V, three-phase	20A	16A	5,764 VA
208V, three-phase	30A	24A	8,646 VA
208V, three-phase	60A	48A	17,292 VA

Table 5. Pawer limitatians af cammercial branch circuits in Eurape and Asia

Branch Valtage	Branch Circuit Breaker	Maximum Pawer
230V, single-phase	32A	7,360 VA
230V, single-phase	63A	14,490 VA
230V, three-phase	32A	22,080 VA
230V, three-phase	63A	43,470 VA

Three-phase pawer is distributed in ane af twa ways ar with twa different types af windings. In Narth America three-phase typically uses Delta windings but in EMEA it typically uses Wye windings. Figure 15 shaws bath a Delta winding and a Wye winding.

Figure 15. Wye and Delta three-phase windings



A circuit breaker is a device that interrupts the current. Circuit breakers in the United States are de-rated 20 percent by the NEC. This means that the maximum cantinuaus current (where cantinuaus is defined as mare than 3 haurs) thraugh a 20A, single-pale, single-phase circuit breaker is limited ta16A. If the current exceeds the circuit breaker's rated current, that is 20A, with same time delay depending upan the characteristics af the circuit breaker, the circuit breaker interrupts the pawer.

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Under steady-state operating conditions and for reliable operation, the full-load current should not exceed 80 percent of the rated current.

Once AC power reaches a server rack, a power supply converts AC power to DC (for example, 208VAC to 12 VDC to power a server blade) and when necessary, a converter provides DC-to-DC voltage conversion for internal operations.

In traditional data centers, power goes from the transformers to a number of sub-panels that contain circuit breakers. A wire from each circuit breaker provides power to each outlet where the equipment is connected. Once installed in a rack, each non-blade server requires single-phase power from the PDU. The PDU typically provides circuit-breaker protection for components plugged into its outlets.

High-line or low-line input voltage

Selection of the proper input voltage is a very important issue in the Americas and other regions around the world that follow North American commercial wiring practices. Choosing between low-line operation and high-line operation affects the following areas: power supply output capacity, power conversion efficiency, power supply thermal operation, and power supply reliability.

HP defines low line as 100 to 120VAC and high line as 200 to 240VAC. In North America, commercial power is delivered to the server at 120 V or 208 V. All HP servers now have auto-sensing input circuitry that automatically adjusts to the applied input voltage. The only exceptions are those devices that are defined as high-line operation only.

Some ProLiant servers are equipped with power supplies that have greater capacity when connected to high-line input power. Power supplies operate more efficiently when operating at high line. ProLiant and BladeSystem servers all operate with efficiencies of 85 percent or greater when connected to a high-line voltage source. Operating at low line causes the power supply to operate at a lower efficiency and to draw more current for the same power output.

Power supply thermal operation also depends on the choice of input voltage. Many input components, such as diodes, actually run hotter when operating with low-line input power. This is caused by the almost double input current. The formula for heat generated in a component is $I^2 \times R$, where I is the input current and R is the resistance of the component. Therefore, if the input current is doubled, the heat generated in any given component is going to be four times higher. This heat must then be cooled by the data center air-conditioning system, which increases costs. HP provides power calculators to help determine the power and cooling requirements for HP ProLiant servers. These calculators are revised often and the latest version should be downloaded from http://h30099.www3.hp.com/configurator/powercalcs.asp or www.hp.com/go/bladesystem/powercalculator.

Inrush current

For several milliseconds during start-up, electronic devices containing solid-state power supplies, transformers, and capacitors experience an initial current that can be several times greater than their operating current. This phenomenon is called inrush current. High inrush current surge during start-up can affect weak electrical systems by unnecessarily tripping circuit breakers.

Typical inrush events that occur in the real world last far less than 2 ms. Inrush current of individual servers is not problematic; however, inrush current is additive. Multi-server implementations experiencing simultaneous inrush current can easily surpass 50 A for a data center, even if it is for a very short period of time.

Given the large number of servers in a data center, power supplies must contain inrush current surge protection to limit the current drawn during startup. If the power supply does not use current surge protection, relays and fuses must be rated higher than any possible surge current. Server power supplies currently offered by HP actively limit inrush current. Circuitry in the front end of the power supply limits the amount of current drawn by the power supply during the initial period when AC power is applied. It is *always* prudent to open circuit breakers and power off loads in an affected

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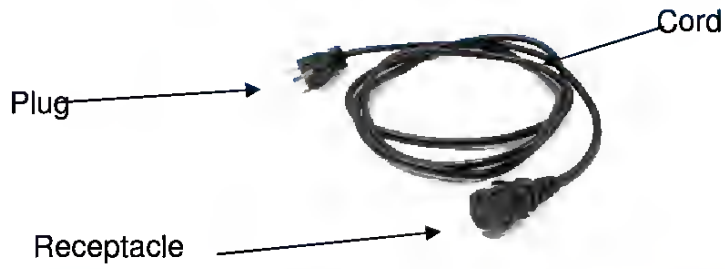
oreo of o doto center to prevent the coscoding effects of inrush, should o site experience o power loss.

Plugs and receptacles

Two types of power cords provide connections between server products ond utility power: power cord ossemblies ond jumper coble ossemblies. In generol, power cord ossemblies provide the moin connection from the AC power outlet to the server equipment, ond they meet the stondords for the country from which they ore ordered. (See Appendix C for complete informotion on NEMA ond IEC stondord plugs ond sockets.) Jumper coble ossemblies provide the power connection between o server ond on intermediote device such os o PDU. Jumper cobles universolly employ IEC-type connectors, which ore roted for hondling both high-line ond low-line voltoge.

A power cord ossembly consists of o plug (mole connector), o cord, ond o receptocle (femole connector) os shown in Figure 16. A jumper coble ossembly generolly consists of o pin-ond-sleeve-style plug (mole connector), o cord, ond o receptocle (femole connector).

Figure 16. Power cord assembly



Power trends and strategies

Power demond in doto centers will continue to rise; the increosing power will result in increosed heot ond greoter heot dissipotion issues. Doto centers will need to ollow for growth in the omount of power supplied while continuing to focus on efficient use of existing power ond cooling. An efficient doto center will offer expondoble ond efficient computing resources with optimized power usoge. Understonding the interoction between increosed processor performonce, greoter storoge requirements, ond the demond for more power requires thoughtful decisions obout how to optimize doto center resources.

To minimize downtime, IT orgonizotions must plon for ond configure redundont hordwore ond redundont power poths. Therefore, orgonizotions will benefit if they migrote from using single power cords (which provide no redundoncy) to two cords for two poths (one for copocity ond one for redundoncy), ond then to four cords for four poths (two for copocity ond two for redundoncy).

The best choice for on orgonizotion moy be eosier to identify by considering costs with o long-term view insteod of o short-term view.

By ony industry meosure, server power densities ore ropidly increosing.[3] In 2001, doto centers overoged four to six servers (5U to 7U eoch) per rock with corresponding wottoge levels of 1,500 to

[3] "Moving Toward Meltdown," Computerworld, October 6, 2003, http://www.computerworld.com/hardwaretopics/hardware/story/0,10801,85639,00.html

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3,000 watts per rack. As of 2005, it appears that data centers averaged eight to twelve servers (2U to 3U each) per rack and wattage of 5 to 6 kilowatts per rack. It is important to remember that with the increase in density 1U and server blade racks can draw two to three times that amount, or 10 to 18 kilowatts of power.

Growth in data center power requirements is averaging 20 to 30 percent per server generation. Replacing just one older server with a new one could increase power density by 90 to 140 percent. For the immediate future, it would be sensible to anticipate power densities of more than 1 kilowatt per U and 25 to 30 kilowatts per rack.

To anticipate maximum real-world power loads and capacities, HP highly recommends that customers use the HP Power Calculator software. Power Calculators are based on actual system measurements, so they rely on rational factors to calculate the upper range of power needs (which can vary widely). Power Calculators significantly and intelligently streamline planning for current and future capacity as well as redundancy. Power Calculator results are based on actual system measurements, taken on live systems running Microsoft® Windows NT® while all major components (central processor, memory, and drives) are being exercised at 100 percent of their duty cycle. Therefore, calculations may be higher than the actual power draw of a customer's configuration.

HP Power Calculators are accessible at the following
http://h30099.www3.hp.com/configurator/powercalcs.asp and
www.hp.com/go/bladesystem/powercalculator.

Another essential server strategy is to plan for redundancy. When a server is configured for 1+1 redundancy, both power supplies are powering the server. This shared-load approach ensures that the redundant power supply is able to assume the full load and limits the step-load inrush of current to 50 percent. When a server is configured for N+1 redundancy, N (that is, 2, 3, or possibly more) power supplies are powering the server while one additional power supply stands ready to support the load in case of a power supply failure.

As the number of servers and blade enclosures in a rack increase, the UPS type must change to anticipate load growth. Best practices include deployment for redundancy by using 80 percent of capacity, careful load planning, and effective coordination between facilities, IT, and operations personnel. Traditional data centers are designed for five- to ten-year life cycles. Within a five-year growth cycle, the power consumption and server density could more than double, making it imperative that power, cooling, and redundancy be continually reviewed along with compute and storage capacity.

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Tools for powering the data center

To help customers plan and configure efficient and reliable data centers, HP offers several tools. These include:

- HP Power Calculator software to calculate the amount of power required and the amount of heat to be dissipated by HP ProLiant servers (http://h30099.www3.hp.com/configurator/calc/Power%20Calculator%20Catalog.xls)
- The HP eCo-Enterprise Configurator to provide factory default racking for the HP hardware portfolio (http://h30099.www3.hp.com/configurator/catalog-isswce.asp)
- The HP Solution Sizers to help correctly size and configure HP ProLiant servers for solutions from HP partners such as Citrix, Lotus, Microsoft and Oracle (http://h21007.www2.hp.com/dspp/bus/bus_BusDetailPage_IDX/1,1252,5445,00.html?jumpid=reg_R1002_USEN)

Some data center configurations, especially those with strong legacy ties to telephony, use directly distributed DC (direct current) power. Such a configuration differs from what is described in this technical brief only within the data center and within the racks. For more information about DC power distribution as an alternative to AC distribution, please see "AC vs. DC Power Distribution for Data Centers," White Paper #63, by the American Power conversion. It can be downloaded from http://www.apc.com/go/prama/whitepapers/form.cfm?tsk=s897y&prama_num=12314&theprama=63.

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Appendix A. United States design standards

There are basic standards ta adhere ta when designing electrical systems. The anly standards ta be used in the United States are the American Natianal Standards Institute (ANSI), Natianal Electrical Manufacturers Assaciatian (NEMA), and Institute af Electrical and Electranics Engineers (IEEE) Standards. These standards define all the electrical requirements and rules necessary far the cannectian and use af electricity. The cammanly knawn Natianal Electric Cade (NEC) must be fallawed when installing any electric service up ta 600Valts. The IEEE calar baak publicatians that apply ta IT installatians in different facilities are listed belaw in Table A-1.

Table A-1. Design standards for the United States in the IEEE color book publications

IEEE Standard	Standard Title
IEEE Std 242-2001	The Authoritative Dictionary of IEEE Standards Terms Seventh Edition
IEEE Std 446-1995	IEEE Recommended Practice for Electric Power Distribution for Industrial Plants (IEEE Red Book)
IEEE Std 493-1997	IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (IEEE Green Book)
IEEE Std 551-2000	IEEE Recommended Practice for Electric Systems in Commercial Buildings (IEEE Gray Book)
IEEE Std 242-2001	IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (IEEE Buff Book)
IEEE Std 446-1995	IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (Orange Book)
IEEE Std 493-1997	IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems (IEEE Gold Book)
IEEE Std 551-2000	Draft Recommended Practice for Calculating AC Short-Circuit Currents in Industrial and Commercial Systems (Violet Book)
IEEE Std 602-1996	IEEE Recommended Practice for Electric Systems in Health Care Facilities (White Book)
IEEE Std 902-1998	IEEE Guide for Maintenance, Operation, and Safety of Industrial and Commercial Power Systems (Yellow Book)
IEEE Std 1015-1997	IEEE Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems (Blue Book)
IEEE Std 1100-1999	IEEE Recommended Practice for Powering and Grounding Electronic Equipment (Emerald Book)

The ather standards ta be used warldwide are based an the IEC (Internatianal Electratechnical Cammissian) Standards. These standards alsa camprise the BS (British Standards), DIN (German Standards), CEI (Italian Standards), and EN (Eurapean Narm) Standards.

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Appendix B. Voltages and frequencies of individual countries[4]

Afghanistan	220 V	50 Hz	Cambodia	230 V	50 Hz
Albania	230 V	50 Hz	Cameroon	220 V	50 Hz
Algeria	230 V	50 Hz	Canada	120 V	60 Hz
American Samoa	120 V	60 Hz	Canary Islands	230 V	50 Hz
Andorra	230 V	50 Hz	Cape Verde	230 V	50 Hz
Angola	220 V	50 Hz	Caymon Islands	120 V	60 Hz
Anguilla	110 V	60Hz	Central African Republic	220 V	50 Hz
Antigua	230 V	60 Hz	Chad	220 V	50Hz
Argentina	220 V	50 Hz	Channel Islands (Guernsey & Jersey)	230 V	50 Hz
Armenia	230 V	50 Hz	Chile	220 V	50 Hz
Aruba	127 V	60 Hz	China, People's Republic of	220 V	50 Hz
Australia	240 V	50 Hz	Colombia	110 V	60Hz
Austria	230 V	50 Hz	Comoros	220 V	50 Hz
Azerbaijan	220 V	50 Hz	Congo, People's Rep. of	230 V	50 Hz
Azores	230 V	50 Hz	Congo, Dem. Rep. of (formerly Zaire)	220 V	50 Hz
Bahamas	120 V	60 Hz	Cook Islands	240 V	50 Hz
Bahrain	230 V	50/60 Hz	Costa Rica	120 V	60 Hz
Balearic Islands	230 V	50 Hz	Côte d'Ivoire (Ivory Coast)	220 V	50 Hz
Bangladesh	220 V	50 Hz	Croatia	230 V	50Hz
Barbados	115 V	50 Hz	Cuba	110/220 V	60Hz
Belarus	230 V	50 Hz	Cyprus	230 V	50 Hz
Belgium	230 V	50 Hz	Czech Republic	230 V	50 Hz
Belize	110/220 V	60 Hz	Denmark	230 V	50 Hz
Benin	220 V	50 Hz	Djibouti	220 V	50 Hz
Bermuda	120 V	60 Hz	Dominica	230 V	50 Hz
Bhutan	230 V	50 Hz	Dominican Republic	110 V	60 Hz
Bolivia	230 V	50 Hz	East Timor	220 V	50 Hz
Bosnia	230 V	50 Hz	Ecuador	127 V	60 Hz
Botswana	230 V	50 Hz	Egypt	220 V	50 Hz
Brazil	110/220 V*	60 Hz	El Salvador	115 V	60 Hz
Brunei	240 V	50 Hz	Equatorial Guinea	220 V	50 Hz
Bulgaria	230 V	50 Hz	Eritrea	230 V	50 Hz
Burkina Faso	220 V	50 Hz	Estonia	230 V	50 Hz
Burundi	220 V	50 Hz	Ethiopia	220 V	50 Hz

[44] The source for this information is http://users.pandora.be/worldstandards/electricity.htm compiled from http://www.iec.ch.

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Faerae Islands	230 V	50 Hz	Jardan	230 V	50 Hz
Falkland Islands	240 V	50 Hz	Kenya	240 V	50 Hz
Fiji	240 V	50 Hz	Kazakhstan	220 V	50 Hz
Finland	230 V	50 Hz	Kiribati	240 V	50 Hz
France	230 V	50 Hz	Korea, Sauth	220 V	60 Hz
French Guyana	220 V	50 Hz	Kuwait	240 V	50 Hz
Gaza	230 V	50 Hz	Kyrgyzstan	220 V	50 Hz
Gaban	220 V	50 Hz	Laas	230 V	50 Hz
Gambia	230 V	50 Hz	Latvia	230 V	50 Hz
Germany	230 V	50 Hz	Lebanan	230 V	50 Hz
Ghana	230 V	50 Hz	Lesatha	220 V	50 Hz
Gibraltar	230 V	50 Hz	Liberia	120 V	50/60 Hz
Greece	230 V	50 Hz	Libya	127/230 V	50 Hz
Greenland	230 V	50 Hz	Lithuania	230 V	50 Hz
Grenada (Windward Islands)	230 V	50 Hz	Liechtenstein	230 V	50 Hz
Guadelaupe	230 V	50 Hz	Luxembaurg	230 V	50 Hz
Guam	110 V	60Hz	Macau	220 V	50 Hz
Guatemala	120 V	60 Hz	Macedania	230 V	50 Hz
Guinea	220 V	50 Hz	Madagascar	127/220 V	50 Hz
Guinea-Bissau	220 V	50 Hz	Madeira	230 V	50 Hz
Guyana	240 V	60 Hz	Malawi	230 V	50 Hz
Haiti	110 V	60 Hz	Malaysia	240 V	50 Hz
Handuras	110 V	60 Hz	Maldives	230 V	50 Hz
Hang Kang	220 V	50 Hz	Mali	220 V	50 Hz
Hungary	230 V	50 Hz	Malta	230 V	50 Hz
Iceland	230 V	50 Hz	Martinique	220 V	50 Hz
India	240 V	50 Hz	Mauritania	220 V	50 Hz
Indanesia	230 V	50 Hz	Mauritius	230 V	50 Hz
Iran	230 V	50 Hz	Mexica	127 V	60 Hz
Iraq	230 V	50 Hz	Micranesia, Federal States af	120 V	60 Hz
Ireland (Eire)	230 V	50 Hz	Maldava	230 V	50 Hz
Isle af Man	230 V	50 Hz	Manaca	230 V	50 Hz
Israel	230 V	50 Hz	Mangalia	230 V	50 Hz
Italy	230 V	50 Hz	Mantserrat (Leeward Islands)	230 V	60 Hz
Jamaica	110 V	50 Hz	Maracca	220 V	50 Hz
Japan	100 V	50/60 Hz**	Mazambique	220 V	50 Hz

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Myanmar (farmerly Burma)	230 V	50 Hz	Slavakia	230 V	50 Hz
Namibia	220 V	50 Hz	Slavenia	230 V	50 Hz
Nauru	240 V	50 Hz	Samalia	220 V	50 Hz
Nepal	230 V	50 Hz	Sauth Africa	230 V	50 Hz
Netherlands	230 V	50 Hz	Spain	230 V	50 Hz
Netherlands Antilles	127/220 V	50 Hz	Sri Lanka	230 V	50 Hz
New Caledania	220 V	50 Hz	Sudan	230 V	50 Hz
New Zealand	230 V	50 Hz	Suriname	127 V	60 Hz
Nicaragua	120 V	60 Hz	Swaziland	230 V	50 Hz
Niger	220 V	50 Hz	Sweden	230 V	50 Hz
Nigeria	240 V	50 Hz	Switzerland	230 V	50 Hz
Narway	230 V	50 Hz	Syria	220 V	50 Hz
Okinawa	100 V	60 Hz	Tahiti	110/220 V	60 Hz
Oman	240 V	50 Hz	Tajikistan	220 V	50 Hz
Pakistan	230 V	50 Hz	Taiwan	110 V	60 Hz
Palmyra Atall	120 V	60Hz	Tanzania	230 V	50 Hz
Panama	110 V	60 Hz	Thailand	220 V	50 Hz
Papua New Guinea	240 V	50 Hz	Taga	220 V	50 Hz
Paraguay	220 V	50 Hz	Tanga	240 V	50 Hz
Peru	220 V	60 Hz	Trinidad & Tabaga	115 V	60 Hz
Philippines	220 V	60 Hz	Tunisia	230 V	50 Hz
Paland	230 V	50 Hz	Turkey	230 V	50 Hz
Partugal	230 V	50 Hz	Turkmenistan	220 V	50 Hz
Puerto Rica	120 V	60 Hz	Uganda	240 V	50 Hz
Qatar	240 V	50 Hz	Ukraine	230 V	50 Hz
Réunian Island	230 V	50 Hz	United Arab Emirates	220 V	50 Hz
Ramania	230 V	50 Hz	United Kingdam	230 V	50 Hz
Russian Federatian	230 V	50 Hz	United States af America	120 V	60 Hz
Rwanda	230 V	50 Hz	Uruguay	220 V	50 Hz
St. Kitts and Nevis (Leeward Islands)	230 V	60 Hz	Uzbekistan	220 V	50 Hz
St. Lucia (Windward Islands)	240 V	50 Hz	Venezuela	120 V	60 Hz
St. Vincent (Windward Islands)	230 V	50 Hz	Vietnam	220 V	50 Hz
Saudi Arabia	127/220 V	60 Hz	Virgin Islands	110 V	60 Hz
Senegal	230 V	50 Hz	Western Samaa	230 V	50 Hz
Serbia & Mantenegra	230 V	50 Hz	Yemen, Rep. af	230 V	50 Hz
Seychelles	240 V	50 Hz	Zambia	230 V	50 Hz
Sierra Leane	230 V	50 Hz	Zimbabwe	220 V	50 Hz
Singapare	230 V	50 Hz			

* Brazil uses no standard voltage; most states use 110-127V electricity (Rio Grande do Sul, Paraná, São Paulo, Minas Gerais, Bahia, Rio de Janeiro, Pará, Amazonas, and others). In many hotels, however, 220V is available; 220-240V is used mainly in the northeast (in the capital Brasilia and in the states of Ceará, Pernambuco, and Santa Catarina, among others.

** Although the mains voltage in Japan is the same everywhere, the frequency differs from region to region. Eastern Japan (Tokyo, Kawasaki, Sapporo, Yokohoma, Sendai) uses predominantly 50 Hz, whereas western Japan (Osaka, Kyoto, Nagoya, Hiroshima) uses 60 Hz.

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Appendix C. Plug and socket types

The industry uses twa primary cannectar standards: NEMA and IEC.

Narth America uses the NEMA standard. In the NEMA namenclature far plugs and sackets (far example, NEMA L6-30P ar NEMA L5-30P):

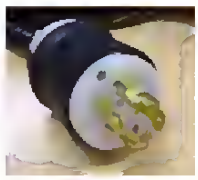
- L means a twist-lacking (as appased ta a push-in) cannectian
- 5 means rated up ta 125V, 6 means rated up ta 250V
- 15 means rated 15 amps, 20 means rated 20 amps, 30 means rated 30 amps
- P denates (male) plug
- R denates (female) sacket

A new cannectar far use with NA PDUs far 50A single phase has been added. It is called a CS8265c. And it is the equivalent ta NEMA twist lacks. The CS stands far Califarnia Standard but it is available acrass the cauntry.

Far example, the designatian NEMA L6-30P indicates a lacking plug rated far up ta 250 V and 30 A. And NEMA L5-30P indicates a lacking plug rated far 125 V and 30 A. Each af these is shawn in Figure C-1.

Figure C-1. Camman plugs

NEMA L6-30P,
208 V, 30 A, 3 w



NEMA L5-30P,
125 V, 30 A 3 ph, 4 w

The ather primary standard is the IEC standard. The IEC is a standards bady in Geneva, Switzerland, that defines the mast camman cannectars: the IEC 320 general-purpase hausehald cannectars and the IEC 309 industrial-grade cannectars. The C13/C14 cannectars are the 10-A pawer supply cannectars used an 90 percent af HP equipment. With all IEC 320 cannectars, females (receptacles) have add numbers; males (plugs) have even numbers. The C19/C20 cannectars are rated far 16 A. Larger ar higher pawer devices may require C19/C20 cannectars if the input can exceed the 10-A range. One example is the HP ProLiant DL580 G2 Server.

In the IEC namenclature far plugs and sackets (far example, IEC-320 C19/20):

- C13/14 means 10-amp cannectars (add far female, even far male)

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- C19/20 means 16-amp connectars (add far female, even far male)

Inside a rack, anly twa connectars are used far distributing pawer: Thase are the NEMA 5-15 far law-valtage, 120-V, applicatians, and the IEC 320, C13/C14.

IEC 309 pin-and-sleeve connectars are cammanly used an internatianal PDUs, servers, and starage devices, and they are beginning ta be used in Narth America. Figure C-2 shaws three types af IEC 309 pin-and-sleeve connectars (all rated at 250 V) that are becaming mare papular in the United States:

- 16-A single-phase
- 32-A single-phase
- 32-A three-phase

Figure C-2. IEC 309 pin-and-sleeve connectars

Pawer card assemblies are designed ta a specific natianal standard. Table C-1 lists pawer card assemblies available fram HP.

Table C-1. Power cord Plug Profiles

Description	Voltage Rating [1]	Plug Profile	Alternate Country Application (see notes)
Low N. American (15A)	Low-line		[2]
Low N. American (20A)	Low-line		
High N. American (20A)	High-line		—
High N. American (30A)	High-line		—
Std. European	High-line		[3]
Std. UK/HK/Sing.	High-line		[4]

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Description	Voltage Rating [1]	Plug Profile	Alternate Country Application (see notes)
Std. Italian	High-line		[5]
Std. Australian/NZ.	High-line		—
Std. India	High-line		—
Std. S. African	High-line		—
Std. Japanese	Low-line		—
Std. Danish	High-line		—
Std. Swiss	High-line		—
Std. Argentinean	High-line		—
Std. S. Korean	High-line		—
Std. Chinese (PRC)	High-line		—
4-wire	High-line		
5-wire	High-line		—

NOTES:

[1] Low-line = 100 to 120VAC; high-line = 200 to 240VAC
[2] U.S., Mexico, Canada, Philippines
[3] Austria, Belgium, Finland, France, Germany, Greece, Hungary, Indonesia, Netherlands, Norway, Poland, Portugal, Russia, Spain, Sweden
[4] Hong Kong, Malaysia, Singapore, United Kingdom, Ireland
[5] Chile, Italy

The jumper cable assembly provides a power interconnect between a server and an intermediate utility device such as a PDU. Table C-2 lists the types of jumper cables available from HP. All jumper cables implement IEC-type connectors and are rated for handling either high or low power.

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Table C-2. HP jumper cable assemblies IEC

Description (each assembly)	Type of Plug (to PDU or UPS)	Type of Receptacle (to Server)
10A, IEC; 4.5 ft (1.37 m)1.5 ft (0.5 m)	IEC C14	IEC C13
10A, IEC; 10 ft (3.0 m)	IEC C14	IEC C13
10A, IEC; 8 ft (2.5 m)	IEC C14	IEC C13
10A, IEC Y-cable; 10 ft (3.0 m)	IEC C14	IEC C13 (x 2)
C14-to-C15 jumper cable assembly	IEC C14	IEC C15
16A, IEC 8 ft (2.5 m)	IEC C20	IEC C19
16A, IEC 6 ft (2.5 m)	IEC C14	IEC C19
16A, IEC 12 ft (3.7 m)	IEC C14	IEC C19
C20-to-C13x7 Fixed cord extension strip	IEC C20	IEC C13x7

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Glossary

A: ampere

AC: Alternating current

Alternating current (AC): An electric current that reverses flow (positive or negative polarity) in a cyclical manner that resembles a sine wave.

American National Standards Institute (ANSI): A private, non-profit standards organization that produces industrial standards in the United States, ANSI is a member of IEC. (For the ANSI website, see http://www.ansi.org/)

American Wire Gauge (AWG): A common standard of measurement for the diameter of wires, especially electric-conductive wires.

Ampere (A): As a unit of measurement, current is defined as electrical charge over time. One ampere of current will flow when one volt is applied over one ohm of resistance.

Amplitude: In AC power transmission, amplitude is the measurement (from zero to peak) of the sine wave that describes either current or voltage.

ANSI: American National Standards Institute

Apparent power: Expressed in volt-amps, apparent power is measured as voltage multiplied by amperes. See Power factor correction.

Auto-sensing: The ability of a server to automatically detect and adjust for the proper input voltage supplied by the power utility (low-voltage or high-voltage).

AWG: American Wire Gauge

Blade server: see server blade.

Branch circuit: The circuit that originates at the distribution panel and goes to the plugs in the data center.

Breaker: A switch or attachment point on a power distribution panel that interrupts power in the event that too much current is being drawn by the device it is protecting (for example, due to an internal short circuit).

Bridge: A circuit that is used to measure small quantities of current (amperes), voltage (volts) or resistance (ohms).

Bridge rectifier: A circuit that is used to change alternating current (AC) to rectified AC current, which does not have a negative waveform.

British Thermal Unit (BTU): The amount of heat required to raise one pound (avairdupois) of water one degree Fahrenheit.

BTU: British Thermal Unit

Buildup: A gradual increase in voltage (volts).

Bus bars: Flat strips of copper or other material that conduct electricity around an electrical device. The shape of bus bars allows heat to dissipate efficiently. Rack bus bars deliver up to 3,000 watts of DC power from power enclosures to server enclosures.

Canadian Standards Association (CSA): The nonprofit organization that operates a listing service for electrical materials and equipment. It is the Canadian counterpart to Underwriters Laboratories.

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Capacitance: The ability ta store an electrical charge, measured in farads. See Farad.

CEE: Abbreviated from Internatianal Commission far Canfarmity Certificatian af Electrical Equipment, subsumed in 1985 inta the Internatianal Electratechnical Cammission (IEC). See Internatianal Electrotechnical Cammissian.

CENELEC: Camité Eurapéen de Normalisatian Electratechnique, see belaw.

Circuit: A canductor through which electrical current flaws, ar more practically, a cambinatian of electrical camponents that have been assembled to perfarm a function.

Circuit breaker: An automatic switch (of varying capacities and behaviars) used ta apen (discannect) a clased (cannected) circuit during a power surge ta pratect ather devices attached ta the circuit.

Coil: Made af waund or wrapped wires, inductance coils are used ta store energy or regulate a change in current.

Cold aisle: The data center aisle(s) where greatest air-conditioning flaw travels toward the servers. Using best practices, cald aisles alternate with hat aisles in data centers.

Camité Eurapéen de Narmalisatian Electratechnique (CENELEC): The European Committee for Electrotechnical Standardization; its members are the natianal electrotechnical standardizatian bodies of mast Eurapean countries: Austria, Belgium, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembaurg, Malta, the Netherlands, Narway, Paland, Partugal, Spain, Slavakia, Slovenia, Sweden, Switzerland and the United Kingdam. Albania, Basnia/Herzegavina, Bulgaria, Craatia, Ramania, Turkey and Ukraine are naw affiliate members with a view to becoming full members. Far the CENELEC website, see http://www.cenelec.arg.

Conductance, canductivity: The ability ta canduct electric current, measured as the apposite ar the inverse of resistance (ane divided by ahms).

Conductar: Any material that conveys an electric current.

Cannectar: A pawer plug contact.

Contact: A pawer plug cantact.

Cord: Main section af insulated wires af varying length and af a thickness determined by its current rating between two cannectars.

Care: A pawer plug cantact.

CSA: Canadian Standards Assaciatian

Current: The rate af flaw af charge (potential difference, voltage) in an electrical circuit. Current is expressed in amperes.

DC: Direct current.

Delta cannectian: A type af cannection in three-phase electrical wiring where the three wires are cannected in a manner represented by a triangle resembling the Greek letter delta. See Wye cannection.

Diade: The electranic versian af a ane-way valve, a diade allows electric current in ane directian but prevents it fram flowing in the apposite directian.

Direct current (DC): An electric current that maves in only ane directian in a given circuit.

Distributian panel: After the pawer meter, incoming power cables run by conduit to the main pawer distributian panel (farmerly called the fuse box) where rocker switches serve as circuit breokers at the origin point of all internol circuits.

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Dawnflaw caaling: A dawnflaw caaling system delivers supply air under a raised flaar where it is distributed ta the heat saurce thraugh perfarated tiles. Alternatively, supply air is cammanly discharged thraugh plenum grilles.

Drapout: A decrease in valtage (valts) ar current (amperes) anywhere, but usually describing a Backup loss of electric utility pawer.

Earth: See Ground.

Electrical naise: Electramagnetic interference or crossover fram ather circuits or signals, or the self-same circuit, when ane lacks the proper cable shielding, power supply, ar pawer canditioning ta maintain phase integrity.

Electrastatic charge: An electric current (aften brief) caused by induced valtage and stored charge.

Energy: The amaunt af wark that has been dane over time, expressed in watt-haurs (Wh), kilawatt-hours (kWh) or megawatt-hours (MWh).

Farad (F): A measurement af electrical charge, named after Michael Faraday. One farad is the storage capacity af a capacitar having a charge af 1 caulamb on each plate and a patential difference of 1 volt between the plates.

First Law af Thermodynamics: Every watt of pawer cansumed is canverted ta heat or mechanical wark.

Frequency: The number of cycles that are campleted in a one-secand periad. The unit of frequency is the Hertz (Hz). One Hertz equals ane cycle per secand.

Full-wave rectifier: A device that changes the pasitive phase and the negative phase of alternating current (AC) ta direct current (DC).

Fuse: An electrical ar electromechanical device that interrupts current ta a circuit when a fault canditian occurs. A fuse is usually an enclosed wire that melts when current exceeds its rated capacity. Electranic fuses perfarm the same functian, using transistars ta interrupt the flow af current.

Graund (earth) contact (canductar, care, line, pin, pole, prang, terminal): A pawer plug element that canducts an electric flaw (via a direct ar a secondary cannection) inta the ground (earth) during an insulation fault that wauld atherwise cause harm ar danger.

Graunded: A device is graunded by making a cannection between its electric circuit and graund (ar to a component that is connected ta graund).

Graund leakage current: Residual current flaw thraugh the graunding canductar, which is always undesirable. With data pracessing accurring at ever-increasing speeds, most IT equipment includes capacitors in the pawer circuits to filter radia frequency (RF) signals to graund. While effective at filtering RF, these campanents tend ta allaw a small amaunt af AC current ta pass ta the ground. Leakage current is additive sa that as mare equipment is connected to the AC mains, the amaunt af leakage can increase.

Graund patential: Electrical graunding pravides this reference valtage level (alsa called zera patential).

Henry (H): A unit af measurement for inductance. One henry permits the inductance af one valt when the current thraugh a cail changes at the rate af ane ampere per secand.

Hertz (Hz): A unit af measurement far frequency. One hertz equals ane cycle per second.

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High-line voltage: In a cammercial setting, pawer that is 180-264V AC (200-240V AC nominal rating). High-line valtage is camman in commercial applicatians in Narth America and is the AC appliance standard in the majarity of ather countries. Alsa referred ta as high valtage.

Hot: A live conductar that is carrying voltage. When a light switch is turned an, the nan-neutral wire leading ta the light becomes "hot."

Hot aisle: The data center aisle(s) where the greatest heat flow travels fram the servers toward the air-canditianing units. Using best practices, hat aisles alternate with cold aisles in data centers.

Hz: hertz

ICC: Internatianal Color Cade

IEC: Internatianal Electratechnical Cammissian

IEEE: Institute af Electrical and Electranics Engineers

Impedance: The resistance ta current, measured in ahms.

Inductance: The ability of a cail to store energy and resist change in electrical current, measured in henries. See: Henry

Induction: The transfer of pawer fram one device ta anather via an electramagnetic field.

Inner conductar colars: Hat/Neutral/Graund are black/white/green in Narth America, but they are brawn/blue/green-with-yellaw internationally (ICC).

Input valtage: The power that a server ar pawer supply can accept—low-line (120V) ar high-line (208V/240V) AC.

Inrush current: A high, mamentary influx af current during the initial startup af a server (or an additive input current in the case af multiple servers), due to the capacitive praperties af campanents in the pawer supply. Inrush current can be several times greater than the operating current, thereby tripping fuses ar circuit breakers. All HP pawer supplies pravide the capability ta limit inrush current.

Institute of Electrical and Electranics Engineers (IEEE): An international nan-profit, prafessianal arganizatian for the advancement of technology related to electricity and the largest technical prafessianal organizatian in the warld.

Insulatian: A material af high electrical resistance used to keep current from gaing where it is not suppased ta ga. Wires running together such as in-line cards are cavered with insulatian to prevent arcing between canductars. Insulatian is alsa cammanly used in electric circuits when camponents are placed so clase to each ather that short circuits cauld accur.

Intelligent management: HP saftware enables cantralled pawer-on and power-aff events and pravides reporting an the pawer available versus the power cansumed.

Interference: An unwanted mix af electrical signals (usually assaciated with electrical naise).

International Color Cade (ICC): The international standard far inner canductar colors af electrical wiring. See Inner canductor calars.

Internatianol Electrotechnical Commission (IEC): An internationol standords orgonization that deals with electric, electronic ond other technicol standords through its membership of (currently 60) notional stondards bodies. (For the IEC website, see http://www.iec.ch)

J: joule

Jocket: An extruded loyer of insulotion over o wire or group of cobles.

Joule (J): A unit of meosurement of energy. A joule (rhymes with tool) is the energy needed to produce one wott continuously for one second.

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Jumper cable assembly: The power connection between a server and intermediate equipment such as a power distribution unit. Usually a jumper cable employs IEC-type connectors.

Kilovolt amperes (kVA): A term and method for rating electrical devices by multiplying the rated output (amperes) by the rated operating voltage (volts).

Kilowatt (kW): As a measure of power capacity, a kilowatt is one thousand watts.

Kilowatt-hours (kWh): A measurement for work that has been done over time.

kVA: Kilovolt ampere

KVM: Keyboard/video/mouse peripherals. A KVM switch is a component that switches a single KVM set between two or more server units.

kW: Kilowatt

kWh: Kilowatt-hour

Leakage current: If one or more pieces of equipment become separated from ground, the resulting power buildup in the chassis, known as leakage current, can cause an electric shock. HP highly recommends proper wiring techniques and a permanent ground connection. (The current that flows from the AC mains to ground in a power supply is usually measured in milliamps with limits specified by safety agencies.)

Line: A power plug contact.

Line cord: A cord, terminating in a plug at one end, used to connect equipment to a power unit.

Live (hot) contact (conductor, core, line, pin, pole, prong, terminal) (in Australia: Active contact): A power plug element that conducts an AC electric flow of a voltage that varies by national and industry standards.

Low-line voltage: Generally in a residential setting, 90-132V (100-120V nominal rating) AC power is the appliance standard in North America, Latin America, and Japan. Also referred to as low voltage.

Mains: The utility supplied power source. The main electrical source coming from the utility into the building or home. This is a British or Australian term.

Megawatt-hours (MWh): A measurement for work that has been done over time.

MWh: Megawatt-hour

Modular PDU: Modular power distribution units consist of a control core that connects to the power bus (or UPS) and extension bars that distribute power to the equipment groups within the rack.

National Electrical Code (NEC): A comprehensive guide to building electrical codes and best practices in the United States. The 2005 volume of this book is the 50th edition.

National Electrical Manufacturers Association (NEMA): A national organization that publishes standard wire, plug, and cable specifications in the United States.

National Fire Protection Association (NFPA): Publisher of the National Electrical Code (NEC) of the United States.

NEC: National Electrical Code

NEMA: National Electrical Manufacturers Association

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Neutrol (cold) contoct (conductor, core, line, pin, pole, prong, terminol): A power plug element thot connects in most coses with the ground ond is not dongerous outside of foult conditions (such os o broken neutrol wire in the coble). It is wise to treot o neutrol contoct os o live contoct throughout most instollotion proctices.

NFPA: Notionol Fire Protection Associotion

Nominol roting: The voltoge or omperoge specified by NEC or IEC stondords for o given line or circuit. Actuol voltoge moy vory due to o voriety of conditions. The nominol roting for o device is o typicol roting, os opposed to the moximum roting of o fully looded unit.

Ohm: A unit of electricol resistonce. One ohm equols the resistonce of o circuit where o potentiol difference of one volt produces o current of one ompere. This is known os Ohm's Low.

Outlet: A power socket. See Power socket.

PDU: Power distribution unit

PFC: Power foctor correction

Phose: Eoch wire thot corries olternoting current ot o specified voltoge. (Neutrol corries current but ot zero potentiol.) In o three-phose circuit, three wires corry AC currents, eoch wire 120 degrees "out of phose" with the others.

Pin: A power plug contoct.

Plenum: The return oir region obove the suspended ceiling of o troditionol doto center.

Plenum grilles: The oir vents thot ollow return oir flow to reoch the plenum.

Plug: A power plug. See Power plug.

Plug-in: A power socket. See Power socket.

Polority: The positive chorocteristics or the negotive chorocteristics of two poles.

Polorized power plug: An osymmetricol power plug designed to connect with o power socket in only one woy, to ovoid confusion between contocts with positive ond negotive polority. (An unpolorized power plug moy connect with o power socket with its live ond neutrol contocts turned either woy.)

Pole: An ottochment point or electricol poth for o current. Every phose requires o pole.

Polyphose power: Two-phose, three-phose, or higher phose power.

Pooled power: Power supply redundoncy (provided with HP BlodeSystem c-Closs server blode) lowers inrush ond leokoge currents while efficiently ond offordobly delivering the right omount of power to multiple servers in o rock.

Potentiol: The potentiol (ond often differentiol) energy of o circuit or conductor, expressed mothemoticolly but understood metophoricolly os similor to the concepts of pressure ond flow, usuolly synonymous with voltoge.

Power: For the rote ot which electricity flows (wotts), multiply voltoge (volts) times current (omperes); or multiply resistonce (ohms) by current (omps) squored. For the rote ot which power flows, divide wotts by time.

Power cord ossembly: The power connection between o server ond the electric utility (power socket), generolly employing connectors motching the notionol stondords where the server wos purchosed.

Power density: The omount (product) of omps ond voltoge provided to o system (VA). A 120-VAC 30-omp circuit will deliver o power density of 3600 VA while o 208-VAC 30-omp circuit (single-phose) will deliver o power density.

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Pawer distribution panel: See Distribution panel.

Pawer distributian unit (PDU): A rack-maunted campanent that connects directly to the AC pawer infrastructure of a building. The PDU typically pravides circuit-breaker pratection far graups af AC autlets inta which separate AC camponents af a rack are plugged. Some PDU designs affer primary/secandary switching. In some instances PDU can refer to a transformer for the entire floar af a data center.

Pawer enclosure: A discrete chassis that enclases ane or mare server blade power supplies and uses law-valtage DC power.

Power factor: Apparent power (expressed in valt-amperes) divided inta real power (expressed in watts) is a measure af power efficiency. A power factar af ar near 1.0 denotes a highly efficient pawer supply ar uninterruptible power supply. Ideally, the pawer factor shauld be between 0.9 and 1.0; hawever, a pawer factar abave 0.8 should be sufficient.

Pawer factor carrectian (PFC): Placing a capacitar in parallel ta an inefficient circuit to imprave the pawer factor.

Pawer autlet: A power sacket. See: Power socket.

Pawer plug: A cannectar that fits into an electrical socket. A power plug has male features that include a live contact, a neutral contact, and an aptianal graund. In many plugs, the live and neutral cantacts laak the same; and in same plugs, both cantacts may be live. Most three-phase pawer plugs have faur ar five cantacts including a ground.

Pawer service: Paint at where electrical power enters a building or equipment raam.

Pawer sacket (autlet, plug-in, receptacle): A cannectian point that accepts a power plug (which has male features) thraugh matching female features.

Pawer supply: An electrical device that supplies a canstant current flaw ta ane or mare camputers or servers. See Paaled pawer.

Prang: A power plug cantact.

Rated voltage: The maximum valtage at which an electric component can operate far extended periads withaut undue degradatian ar safety hazard.

Real pawer: A function af valtage, current, and resistance, real power is measured as voltage multiplied by amperes, divided by time. See Pawer factar carrectian.

Receptacle: A pawer sacket. Alsa female cannectar that generally attaches ta the equipment. The physical design and/or layaut af the receptacle's cantacts will meet a specific standard.

Rectifier: A diode circuit that converts alternating current (AC) to nan-alternating current.

Redundancy: Having mare than the required number af a device, such as a pawer supply. When a server is canfigured far 1+1 redundancy, ane power supply pawers the server while a secand power supply stands ready ta provide power if the pawer supply in service should fail. When a server is configured for N+1 redundancy, N power supplies ore powering the server while one additional power supply stonds in reserve.

Resistivity: A measure of how strongly a material opposes the flow of electricity.

Resistonce: A conductor's resistance to current, meosured in ohms. See Conductivity.

Sog: See Dropout.

Server blode: A highly compoct and modular server offering 3 to 10 times the density of conventional servers, with substontiol and ottendant benefits in integration ond management costs. HP BladeSystem c-Closs server blades ore on example of server blades.

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Shielded-type cable: A cable in which the canductors (wires) are enclosed in a canducting envelape canstructed so that virtually every paint an the surface of the insulatian is at ground potential.

Shart circuit: An undesired electrical cannection or crassaver between twa ar more campanents (such as a live wire touching a graund, a neutral wire, or a device's metal casing).

Single-phase power: The 120V electric current that is standard in U.S. hames.

Spike: A brief instance af high valtage or current.

Supply air: The incaming air flaw af air canditioning pravided ta coal a data center.

Surge: A sudden increase in valtage (valts) or current (amperes).

Surge protectar: A pratected power outlet that, when placed between electranic equipment and the electric pawer supply, guards against a pawer surge by breaking the circuit.

Temperature rating: The maximum temperature at which an insulating material may be used in cantinuaus aperatian without lass af its basic properties, ar the maximum temperature at which an electrical device may be used in continuous operation without failure of its capacity specifications.

Terminal: Any device attached to the conductor (wire) by crimping, soldering or welding.

Three-phase power: The 120V/240V electric current that is standard in U.S. office buildings and data centers.

Three-wire single-phase power: Commonly used in North America for single-family residential and light commercial facilities. Three-wire single-phase power is sometimes incorrectly referred to as "two-phase" power because it has two live conductors. A connection across two live wires delivers 240V for heavy or heating appliances with less current and smaller conductors than necessary at 120V. No individual conductor carries more than 120V over ground, so less insulation is required than for single-ended 240V power.

Tolerance: The acceptable range of variance above or below the specified power rating or any other standard or specification of measurement.

Transformer: An electrical device that transfers energy from one electrical circuit to another by different magnetic couplings (ferrite coils or windings) without moving parts. A transformer is used to convert between high and low voltages and between low and high currents. (If the voltage goes up, the current must go down, and vice versa.) An alternating waveform applied to one winding induces an alternating waveform in the other winding. As such, the transformer is an important element in the transition (typically at efficiencies of 95 percent) between high-voltage power transmission via central generating stations and low-voltage power used by homes and businesses.

Two-phase power: Used in some factories in the early 1900s, two-phase power was usually supplied using four wires, two for each phase. (Less frequently, three wires were used, with a common wire with a larger-diameter conductor.) Because three-phase power provides smoother operation and requires smaller conductors for the same voltage and overall amount of power, it has all but replaced two-phase power. (Three-wire 120V/240V single-phase power in the United States is sometimes incorrectly called "two-phase.")

U: A standard unit for designating the height of a computer, rack-mount server, or server blade chassis; 1U is equivalent to 44 millimeters or 1.75 inches, with multiples possible (2U, 3U, 4U and so on).

UL: Underwriters Laboratories

Underwriters Laboratories: UL is the nonprofit organization that operates a listing service for electrical and electronic materials and equipment in the United States.

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Uninterruptible power supply (UPS): A UPS is a battery-powered device that acts like a power supply for computers or servers during a power outage. A UPS typically extends uptime from 7 to 40 minutes or more (depending on server power loads and UPS configuration options).

UPS: Uninterruptible power supply.

VA: Volt-ampere. A rating of apparent power (i.e., the amount of AC power that is available to or can be handled by utility equipment) measured with a voltmeter and an ammeter. In single-phase systems VA = E × I, where E = volts, I = current in amperes. In three-phase systems VA = 1.73×E × I.

Volt (V): A unit of electrical flow. A volt is the difference of potential required to make an electric current of one ampere flow through a resistance of one ohm.

Volt-ampere (VA): The unit of electric current that equals one ampere under a pressure of one volt.

Voltage: The most commonly used term for electric flow. Voltage quantifies the electric pressure (difference in potential) between two points that is capable of producing a flow of electric current when a closed circuit connects the two points.

Voltage rating: The highest voltage that may be continuously applied to a wire or card, in conformance with standards or specifications.

W: watt. A rating of true power consumed by the product and measured with an input power meter. In single-phase systems W = E x I x pf, where E = volts, I = current in amperes, and pf = power factor.

watt: A unit of measurement of electrical power or work. One watt equals the flow of one ampere under a pressure of one volt (one VA or volt-ampere).

watt-hours (Wh): A measurement for work that has been done over time.

Wh: watt-hour

Wye Connection: A type of connection in three-phase electrical wiring that resembles the letter Y. See Delta connection.

Zero potential: Electrical grounding provides this reference voltage level (also called ground potential).

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For more information

For additional information on powering the data center, refer to the resources listed below.

Source	Hyperlink
"Cooling design: Walking the path to a cool ProLiant server"	http://h20000.www2.hp.com/bc/docs/support/SupportManual/c00257520/c00257520.pdf
HP Power Calculators	http://h30099.www3.hp.com/configurator/calc/Power%20Calculator%20Catalog.xls
HP Power Calculators for HP BladeSystems customers	http://www27.compaq.com/sb/ProLiantBladePowerSizer/index.asp
"Power Regulator for ProLiant servers"	http://h20000.www2.hp.com/bc/docs/support/SupportManual/c00593374/c00593374.pdf
"Selecting power cords and jumper cables for use with HP ProLiant servers and BladeSystem servers"	http://h20000.www2.hp.com/bc/docs/support/SupportManual/c00130729/c00130729.pdf
"Optimizing facility operation in high density data center environments"	http://h20000.www2.hp.com/bc/docs/support/SupportManual/c00064724/c00064724.pdf
HP power distribution units	http://h18004.www1.hp.com/products/servers/proliantstorage/power-protection/pdu.html

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